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Quarterly Technical Report

Further Development and Limited Flight Testing of the CycloCrane

Sponsored by
DEFENSE ADVANCED RESEARCH PROJECTS AGENCY,
DARPA/ASTO

CYCLOCRANE PROGRAM:
FURTHER DEVELOPMENT AND
FLIGHT DEMONSTRATION

ARPA ORDER NO. 6390.2 and 3

Issued by DARPA/CMO
under Contract
MDA972-88-C-0058

June 30, 1989

AeroLift Inc.
4105 Blimp Blvd.
Tillamook, OR 97141
(503) 842-8891

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SUMMARY

A program of further development and limited flight testing was initiated by AeroLift on July 16, 1988 and the results of the work accomplished from April through June 30, 1989 are continued in this fourth quarterly report. The basic scope of this program is to identify military missions, develop design configurations, refurbish and modify the existing CycloCrane, demonstrate operational procedures, and develop a~~n R&D~~ program plan. A detailed plan for the implementation of the present program has been developed and the costs and schedules associated with the plan are being monitored and managed.

Due to a redirection of focus mandated by DARPA, the mission analysis element of the program was terminated on June 30, 1989. Because of this redirection, several high-probability military missions had to be abandoned.

The Design Development element was also redirected, the primary effort now being to support the refurbishment and modification of the X.2 CycloCrane.

The refurbishment task is essentially complete, the remaining major tasks being adjustment of the aircraft flight controls and the rigging.

Modification tasks completed during the quarter include the design and stress analysis of the 'Y' tail and fabrication of approximately half of the detail parts for same. The hydraulic system has been inspected and checked, most engine tests have been completed, and bench tests of the avionics systems are complete.

The flight test plan was cleared for open publication in May. Although there has been some slippage, this document will serve as AeroLift's primary document for conducting the limited flight tests. As of June 30, AeroLift had tested and modified the Hirth F-30 engine. Rotating mode tests will be performed in the next quarter prior to flight testing. Ten operational tests were performed on the 36 foot model; the results will be included in the Final Test Report. Additional ground handling exercises are planned for the next quarter.

PREFACE

A program of further development and limited flight testing of the CycloCrane is being conducted by AeroLift Inc. for Defense Advanced Research Projects Agency under contract #MDA972-88-C-0058.

This Fourth Quarterly Technical Report contains the results of the technical work accomplished for April 1, 1989 through June 30, 1989.

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LIST OF EXHIBITS

1.0 INTRODUCTION

Since July 16, 1988, AeroLift has been working under contract to DARPA on a program of further development and limited flight testing of the CycloCrane. The objectives of the program are summarized as follows:

- o Identify mission for which the CycloCrane can fulfill the needs of the United States military services on a cost-effective basis.
- o Develop CycloCrane design configurations to meet the specified mission needs.
- o Demonstrate safe and efficient operational procedures.
- o Establish agency sponsorship for an on-going CycloCrane development.
- o Scope potential R&D programs for prototype development.

This document is the fourth Quarterly Technical Report prepared to meet the requirements of the current contract and contains the results of the work accomplished through June 30, 1989. The report is arranged in accordance with the technical elements of the work breakdown structure presented in the detailed plan.

- o Mission Analysis
- o Design Development
- o Refurbishment and Modifications
- o Testing

As of June 30, 1989, work for AeroLift was completed by the following subcontractors:

- o BDM Corporation - Surveillance Mission Analysis
- o Computer Systems Center - Minesweeping Mission Analysis
- o Oregon State University - Structural Analysis
- o Tension Structures - Structural Analysis
- o John W. Leonard - Structural Analysis

In addition, AeroLift continues to work closely with the Contracting Officer's Technical Representative (COTR), DARPA/ASTO, and the government's technical support contractor, Aerospace Corporation, to ensure that key technical milestones are met and objectives of the program are achieved.

2.0 MISSION ANALYSIS

2.1 Counterdrug

AeroLift briefed Captain Ted Grabowsky, Drug Czar Bennett's Chief of Staff, and requested that office include the CycloCrane counterdrug concept, as exemplified in Exhibit 1, "Project First Defense," (attached) in their requirements. Although we have received no commitment, Grabowsky stated he liked the CycloCrane and the First Defense concept and would give our proposal serious study as the Drug Czar develops his national strategy, due September 5, 1989.

AeroLift briefed Captain Generlick, Colonel Dick Rybak (J-3 USLANTCOM), and members of the JTF-4 staff. As JTF-4 is currently preparing operational plans and requirements to submit to LANTCOM and OJCS, this is an excellent opportunity to have the CycloCrane included as a requirement. Up to the point of shutdown of the Mission Analysis work element on June 30, 1989, AeroLift continued discussions with the DOD Office of Counterdrug Support (General Olmstead), looking for a possible demonstration test from the Army Staff's SASS or semi-submersible platform in June 1990.

Additionally, AeroLift has briefed Betac Corporation, which has an existing support contract with OSD to aid in the development of counterdrug requirements identification. Betac plans to use the briefing material provided by AeroLift in submissions to OSD and DARPA.

AeroLift briefed Lt. General Sidney Weinstein, Assistant Chief of Staff of the Army, with the objective of having Weinstein appoint a staff officer for the CycloCrane in the Counterdrug and Corps Rear Area Surveillance roles.

2.2 Antisubmarine Warfare

Pursuant to the request of the Naval Ocean Systems Center (NOSC), AeroLift had planned to participate in further meetings in San Diego to clarify requirements and assist in integrating the CycloCrane into their plans. However, the departure of Dr. Lewis and directives from DARPA have precluded further development in this mission area.

2.3 Mine Countermeasures

As a result of last quarter's memorandum from SPAWAR and at the request of the Naval Coastal Systems Center (NCSC), AeroLift had planned to join the NCSC, accompanied by Dr. Lewis and a representative of Computer Systems Center, in developing a proposal to be submitted to DARPA for testing and evaluating the X.2 prototype in the MCM role. Additionally, the Pentagon had requested a requisition point paper from Panama City which would have been addressed during that visit.

Again, Dr. Lewis' departure and directives from DARPA have precluded further development in this mission area.

2.4 U.S. Army Instrumented Training

AeroLift continued during this quarter to work closely with the DARPA SIMNET office in developing details of the "seamless simulation" program.

2.5 Corps Rear Area Surveillance

AeroLift briefed Lt. General Weinstein, who indicated he would investigate the possibilities of assigning a staff officer. He evinced interest in the CycloCrane and concurrence in the need for an office in charge of the Corps Rear. Further briefings have been cancelled pursuant to DARPA directive.

2.6 U.S Forest Service

Internal investigation by the USFS disclosed that the current maximum altitude of the X.2 is insufficient to permit fire retardant test participation. However, the USFS remains interested in the CycloCrane and wishes to pursue such testing when we have a model available which will reach at least a 5,500- to 6,000 foot altitude.

2.7 AID Silt Removal

During the quarter, AeroLift briefed ARENA and in-country AID personnel in El Salvador. We also briefed Emily Leonard, AID's Desk Officer at the Department of State, suggesting AID sponsor a 60-day study to assess the feasibility of this project. She requested that we contact ARENA and ask them to request the study through the U.S. Embassy to enable her to respond more rapidly. This effort will be pursued when funds become available to support marketing.

2.8 Parametric Models

In response to requests from potential customers, several parametric models were run, including a 10-ton dual-rotor turboprop version for the Army Training mission and a single-rotor for the Corps Rear Area. These studies are shown in Exhibits 2 and 3, appended to this report.

2.9 Close-Out

During the quarter, it was determined by DARPA that all mission analysis activities under this contract should cease at the end of June and attention be focused on refurbishment and flight testing of the X.2. As a result, the Arlington, Virginia office was closed on June 30, 1989; support staff laid off; and professional staff reassigned.

The counterdrug and Army training efforts as of June 30, 1989 continued to show great promise, but results are not expected in the short term.

3.0 DESIGN DEVELOPMENT

During this reporting period, the primary effort in Design Development was redirected to support the refurbishment and modification of the X.2, analyzing previous X.2 flight data, and investigating various tether systems for field operations.

Work performed on Mission Analysis is reported in the Mission Analysis section, which consisted of evaluating various CycloCrane configurations for military missions such as Army Rear Area Surveillance and Navy Countermines. The parametric model was modified to include Dual Rotor type CycloCranes; however, the rotating cruise analysis was not completed before redirection.

After redirection, single line tether testing on the 36 foot model with various tail configurations was continued. The results showed that an inverted "Y" tail would provide a significant increase in stability over the existing tail when using a single line tether. A decision was, therefore, made to incorporate this into the X.2.

A "Y" tail was designed and is now being fabricated to mount inside the existing X.2 Ring Tail before flight testing begins. This will allow a demonstration of tethered mooring during the flight test program in wind speeds up to 49 MPH. Further investigation into tethered mooring systems is still in progress and an analysis is included in this report.

Data obtained during the previous flight test program was reduced and plotted by Kohlman Systems. This data is in the process of being analyzed to obtain a better understanding of the X.2 from a structural, aerodynamic, and control response viewpoint.

3.1 "Y" Tail Configuration

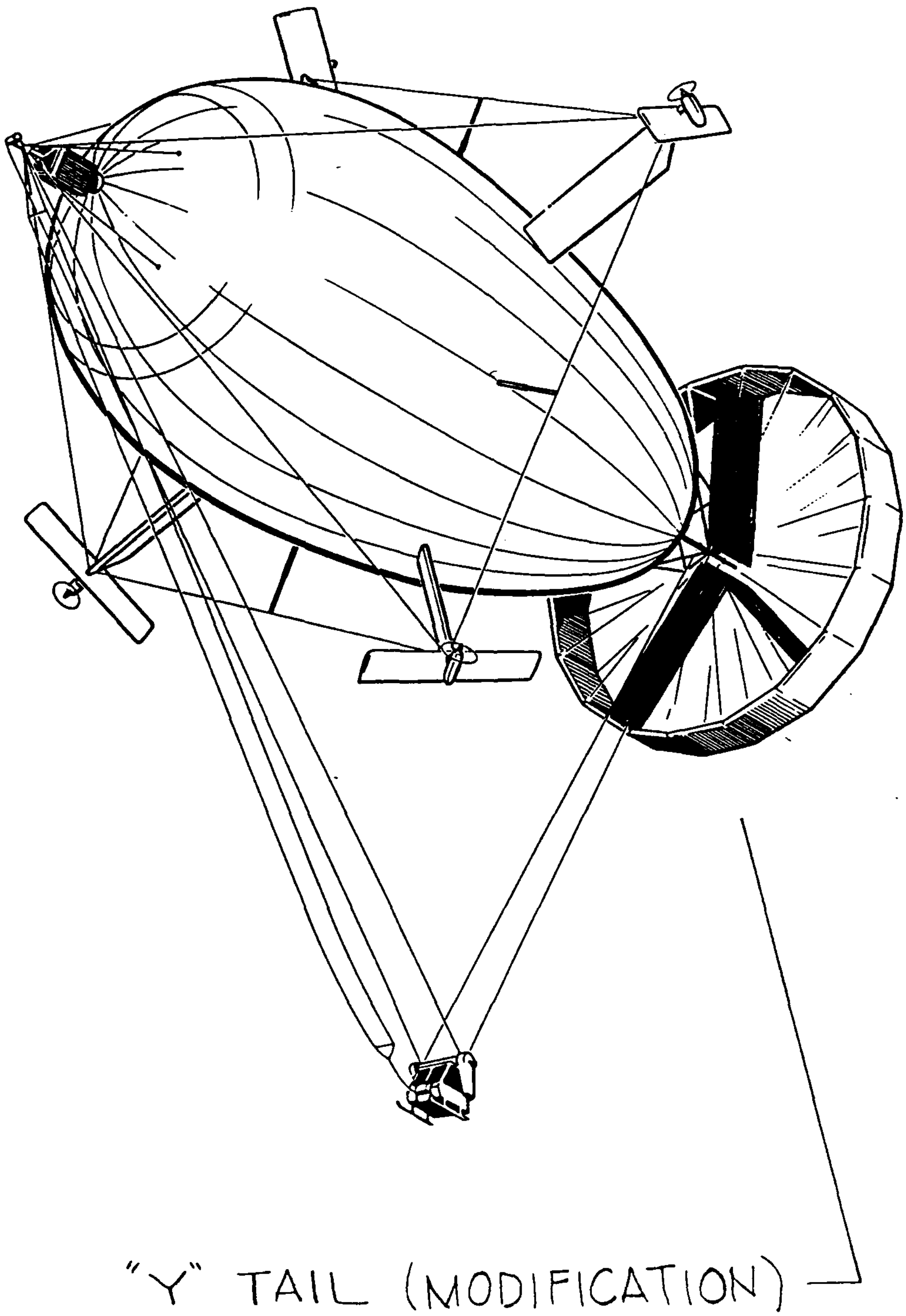
As part of an ongoing program to determine an optimum "off the mast" mooring system for the CycloCrane, a series of tow tests was initiated on the 36 foot model to find a viable tethering system using a single line tether as shown on Exhibit 4, following this page.

As a result of extensive tow testing of the 36 foot model using a single line tether, an inverted "Y" tail was determined to be the best from the perspectives of both weight and stability. The tow speed of the 36 foot model was raised from 20 MPH with a Ring Tail only, to 30 MPH with a Ring Tail plus the inverted "Y".

The results were obtained by visual observation of the 36 foot model's behavior in various wind conditions by towing along a 5,000 foot runway. The mode of instability appeared to be stalling of either the wings or blades with the 36 foot model side slipping to the ground. Recovery was initiated by stopping the tow truck.

Converting the results of the 36 foot model tests to an X.2 sized aircraft gives a tow speed of approximately 60 MPH using a calculated dynamic scaling factor of 1.96.

EXHIBIT 4



"Y" TAIL (MODIFICATION)

These tests demonstrate that, by using a 1.5 safety factor on the dynamic pressure, the X.2 can be tethered in winds where the maximum wind gusts do not exceed 49 MPH.

3.2 "Y" Tail Design

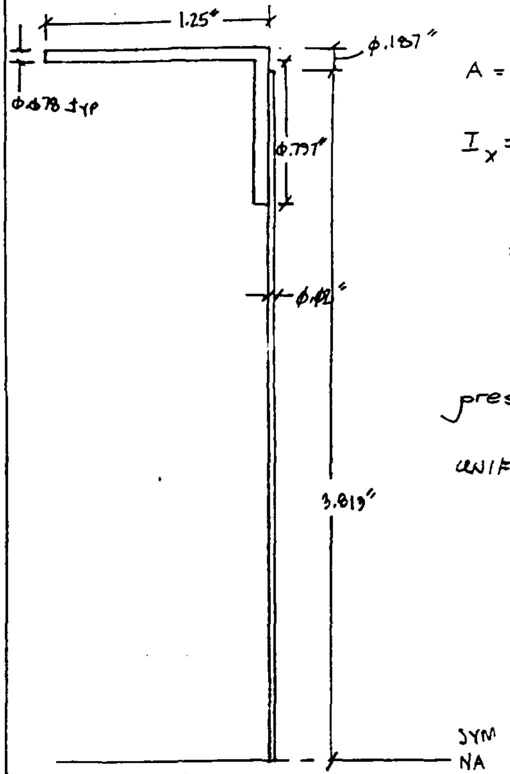
Using conservative assumptions on aerodynamic loading, a "Y" tail was designed to fit inside the existing X.2's Ring Tail.

The "Y" was assumed to resist all of the drag loads from both the Ring and "Y" and transfer them to the center tube. The lift forces on the "Y" tail were calculated assuming a C factor of 1.0 and an 88 ft/sec wind speed at standard sea level conditions. This would give a safety factor of 1.5 at the maximum allowable wind speed of 49 MPH. The loads caused by these conservative assumptions are low and the design of the tail was driven by the manufacturing requirements of minimum gage material. A properly designed tail using composites would be much more efficient, but was not considered because of time constraints.

The "Y" tail also adds considerable stiffness to the existing Ring Tail and reduces the tension in the wires of the Ring Tail. The reduced tension in the wires lowers the compressive stress in the Ring Tail and insures the safety margins in the structure connecting the Ring Tail segments.

The aerodynamic loads on the tail were derived from the forces required to stabilize the vehicle in yaw and pitch and assume the worst possible case. The stresses in the structure are small; consequently, the structure is designed for minimum gage material. The following pages provide details of these analyses.

FORWARD SPAR



$A = ((.078)(1.25) + (.797)(.078) + (.02)(3.813))(2) = 0.4719\ \text{IN.}^2$

$I_x = 2\left(\frac{1.25 \times .078^3}{12} + \frac{0.797^3 \times .078}{12} + (1.25)(.078)\left(4 - \frac{0.78}{2}\right)^2 + (0.797)(.078)\left(4 - .078 - \frac{.797}{2}\right)^2 + \frac{.02 \times 3.813^3}{3}\right)$

$= 5.3489\ \text{IN.}^4$

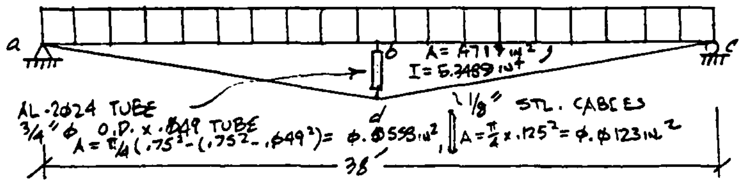
pressure loading $= .66\ \text{lb}/\text{ft}^2$

UNIFORM LOADING ON FORWARD SPAR $= \frac{6-.5}{8.2} \times .66 \times 12$

$= 5.31\ \text{P}/\text{ft}$

$E_{ST} \rightarrow 29000000\ \text{psi}$

$E_{AL} \rightarrow 10.5 \times 10^6\ \text{psi}$



USE FORCE METHOD TO SOLVE FOR UNKNOWN FORCES

LET P_{bd} BE REDUNDANT

$\therefore \Delta_{bo} = \frac{5 \times 5.31 \times 38^4 \times 1728}{384 \times 10.5 \times 10^6 \times 5.3489} = 4.4357.$

PLACE UNIT FORCE bd

$\Delta_b' = \sum \frac{u^2 L}{AE} + \sum \int \frac{m^2 dx}{EI} = \frac{2 \times 3.1667^2 \times 19 \times 12}{10.5 \times 10^6 \times .4719} + \frac{2 \times 3.2059^2 \times 19.2354 \times 12}{0.0558 \times 10.5 \times 10^6} + \frac{1^2 \times 3 \times 12}{0.0123 \times 29 \times 10^6}$

$+ \frac{1 \times 38^3 \times 1728}{48 \times 5.3489 \times 10.5 \times 10^6} = 0.0443\ \text{IN.}$

$\therefore P_{bd} = -4.4357/.0443 = 100.14\ \text{lb.}$

$\therefore \Delta = \left(1 - \frac{1\phi\phi.14}{5.31 \times 38}\right)(4.4357) = 2.23$ IN.

$\therefore$ AXIAL FORCE IN SPAR $= \frac{1}{2} \times 1\phi\phi.14 \times \cot 8.97 = 317.11$ lb.

MAXIMUM BENDING MOMENT IN SPAR $= \left(\left(5.31 \times 38 \times \frac{1}{2}\right) - \frac{1\phi\phi.14}{2}\right)(19) - \frac{5.31 \times 19^2}{2}\Big)$

$+ \underbrace{317.11 \times 2.23}_{P\Delta} = 714.28$ P-IN.

$\therefore f_b = \frac{714.28 \times 4}{5.83489} = 489.66$ psi

$f_a = \frac{317.11}{\phi.4719} = 671.99$ psi

CHECK INTERACTION:

LONG COLUMN : $L = 19.\phi$ $k = 2.\phi$

$\therefore P_{CRITICAL} = \frac{\pi^2 \times 1\phi.5 \times 1\phi^6 \times 5.38489}{(2.\phi \times 19 \times 12)^2} = 2683.71$ lb.

$M_{ULT.} = 2\left(1.26 \times .\phi 78\left(4 - \frac{.\phi 78}{2}\right) + (1.797 \times .\phi 78)\left(4 - .\phi 78 - \frac{.797}{2}\right) + \left(.\phi 2 \times \frac{3.813^2}{2}\right)\right) 64\phi\phi\phi = 96\phi 8\phi.52$ p-in.

$e. = {}^{714.28}/_{317.11} = 2.25$ IN.

$e_o = \frac{96\phi 8\phi.52}{2683.71} = 35.8\phi$ IN

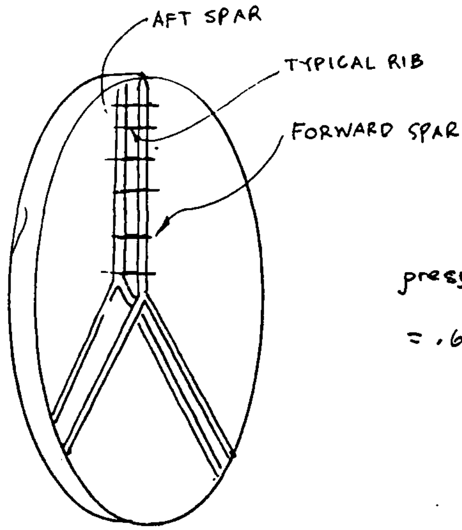
$R_e = {}^{e}/_{e_o} = {}^{2.25}/_{35.8\phi} = \phi.\phi 629$, $n = {}^{P_o}/_{P_e} = {}^{317.11}/_{2683.71} = \phi.1182$

$\therefore R_a = {}^{P}/_{P_o} = .85$

$P_u = .85 \times 2683.71 = 2281.15$ lb.

$\boxed{F.S. = {}^{2281.15}/_{317.11} = 7.19}$

SUMMARY: DEFLECTIONS ARE 2.25 INCHES IN 38 FT. WHICH IS ϕ.5% AND ACCEPTABLE
MARGINS OF SAFETY ARE QUITE HIGH AND ACCEPTABLE.



pressure on spar configuration

$= .66\ \#/ft^2$

Y-BAR SYSTEM REPLACES THE EXISTING CROSS-BAR ANALTSIS.

THIS ANALYSIS IS A COMPLIANCE CHECK OF THE Y-BAR SYSTEM.

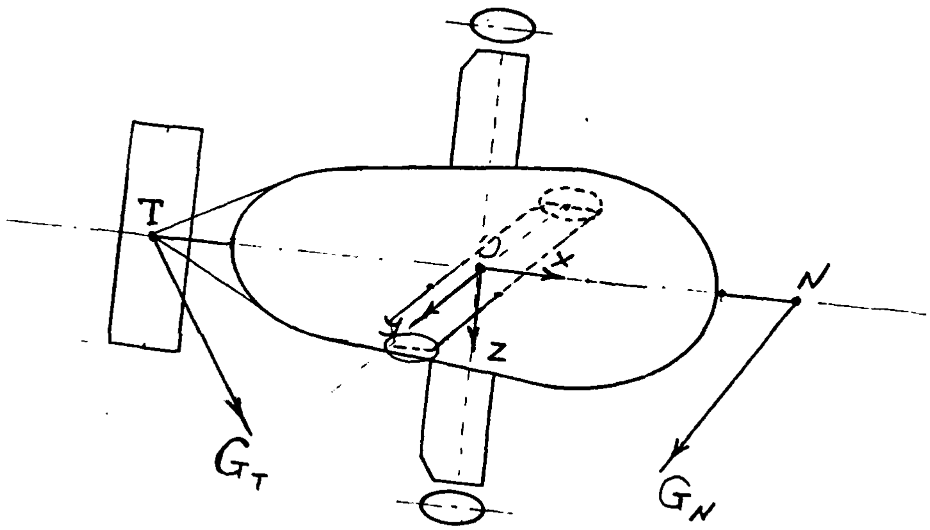
THE Y BAR SYSTEM IS COMPRISED OF TWO SPARS WITH RIBS SPANNING BETWEEN THEM. THE FORWARD SPAN TAKES 2/3 OF THE PRESSURE LOADING. STEEL CABLES STAY THE SPAR FOR EXCESSIVE DEFLECTION AND PREVENT LARGE STRESSES.

THE ANALYSIS SHOWS ALL STRESSES AND DEFLECTIONS ARE ACCEPTABLE. ONLY CALCULATIONS ARE PERFORMED FOR THE FORWARD SPAR AS PREVIOUSLY NOTED, IT CARRIES THE MAJORITY OF THE LOADING AND HENCE THE AFT SATISFIES BY INSPECTION.

3.3 Math Model and Control of the CycloCrane

A six degree of freedom non-linear flight dynamic simulation program has been created to apply to the X.2 CycloCrane. The flight simulation is termed "non-linear" because the forces and moments are non-linear functions of vehicle orientation and velocity.

The equations of motion are referenced to a body-fixed frame whose origin is located at the center of gravity, c.g., of the rotating system plus tail. The center of buoyancy is assumed to be 0.74 ft behind the c.g. The degrees of freedom employed are vehicle roll, pitch and yaw, forward, lateral and vertical velocities. The X-axis points toward the nose along the hull axis of rotation. The Z-axis is the down axis. (X,Y,Z) is a right triple. (See figure below.)



Picture 1

The cab and payload support systems are assumed to be rigid for pitching motions and it is assumed that their lateral motion with respect to the vehicle has high velocity damping so this motion is neglected in the model.

Total cab and payload effects are represented by two forces, G_T and G_N, (see Picture 1 above) applied to the tail and nose of the CycloCrane.

The principle behind the simulations is simple. At the beginning of a "flight," the vehicle is given an initial orientation and velocity. The orientation and velocity allow the program to calculate the relative wind components, in the body fixed frame. Aerodynamic, buoyant, gravity and thrust forces are then calculated and accelerations of the six degrees of freedom are solved using Newton's second law. These accelerations are then integrated over a time step by special modification of Euler-Lagrange's method to find the velocity and orientation at the new instant in time. This process is repeated over and over to produce a simulated flight. Note that special formulas for lift and drag (as vector forces) were created using matrix algebra.

The program contains sub-routines that calculate all the aerodynamic forces and moments on each airfoil surface of the CycloCrane.

The input data required include mass and geometric properties as well as aerodynamic parameters of the vehicle. These must be determined before running the simulation. Other inputs required include control commands that are calculated by the control program and designed to make feedback control loops for the vehicle. Lypunov's second method was used to create these feedback loops and to make the closed loop system asymptotically stable.

It should be noted that after using 1985 X.2 flight data for the simulation, it was found that in the present configuration of the two-ton CycloCrane, there is a problem of reverse controls in simple forward flight. This means that increasing the angle of attack for the 1st and 3rd winglets causes a pitch down of the vehicle. This undesirable effect must be taken into account and improved by reconfiguration of the CycloCrane.

As a design tool, the simulation can provide an effective means for fine tuning a design and for estimating vehicle dynamics for certification purposes. At the same time the control program can be used for solving autopilot problems of the CycloCrane's generation.

3.4 Longitudinal Stability of Tethered Test Model CycloCrane

Ground handling and mooring of aerostats and airships remain among the more difficult problems of LTA technology. Not the least of the difficulties is in predicting the magnitude of the forces on a restrained aerostat under gusty conditions.

This report presents the results of the past experimental observations as well as analytical predictions of the dynamic behavior of the CycloCrane at tethered conditions.

3.4.1 Review of Previous Studies

H.C. Curtiss, Jr., et al. (Ref. 1) performed analytical studies of dynamic stability characteristics of the CycloCrane with an "X" Tail. He showed that the vehicle was stable in translational flight for two tail surface sizes at flight speeds of 15.7, 31, and 52 knots. Further, it was found that with small tail damping the oscillatory modes of the aerostat were quite low.

William F. Putman carried out wind tunnel tests (Ref. 2) on a CycloCrane model in rotating and nonrotating conditions. Results of the nonrotating aerostat at small incidence angle showed that:

- At small incidence angle and the tail off, the rate of change of side force coefficient with yaw angle was nearly zero and directional stability derivatives had unstable values.

- At large incidence angle both tail on and off exhibited side force and it became positive (less stable).

- It was shown that $\frac{\text{Tail Diameter}}{\text{Aerostat Diameter}} = 1 \text{ to } 1.5$ was adequate to provide stable directional stability for the nonrotating case at an incidence between 5 and 10 degrees.

Results of the rotating aerostat at incidence angle showed that:

- The rotating aerostat was statically stable for a tail size larger than a ratio of 0.5 and tail effectiveness was very pronounced.

- Rotating centerbody tests at an incidence of 90° indicated C = 0.6 and C = 0.3 (based on projected side area) which was due to Magnus effect.

A full scale single line tethered model test (Reference 3) on the X.2 with Ring Tail showed inadequate static stability for moored or flight operation. It was found that the X.2 had a static trim point at 45° of side slip and thus there was a chance for the ship to be blown into the ground by heavy variable winds. To improve the directional stability, an addition cf aerodynamic surface (+ shape) was suggested within the Ring Tail. Based on preliminary results, it appeared that the non-zero trim point could be eliminated and directional stability achieved.

Recently (Reference 4) AeroLift conducted a single line tethering and towing of the 36-foot CycloCrane. It was found that when the blades were cocked in forward flight position, the CycloCrane was able to be towed at up to an equivalent 60 knots airspeed. Further, it was shown that a Ring Tail aerostat would withstand at least 40 knot winds without being forced toward the ground as long as the tail was slightly lower than the nose and it was allowed to weather-cock.

3.4.2 Assumptions

Four degrees of freedom are employed to examine the stability characteristics of the CycloCrane. Further, it is assumed that transitional flight velocity and rotor angular velocity are nearly constant.

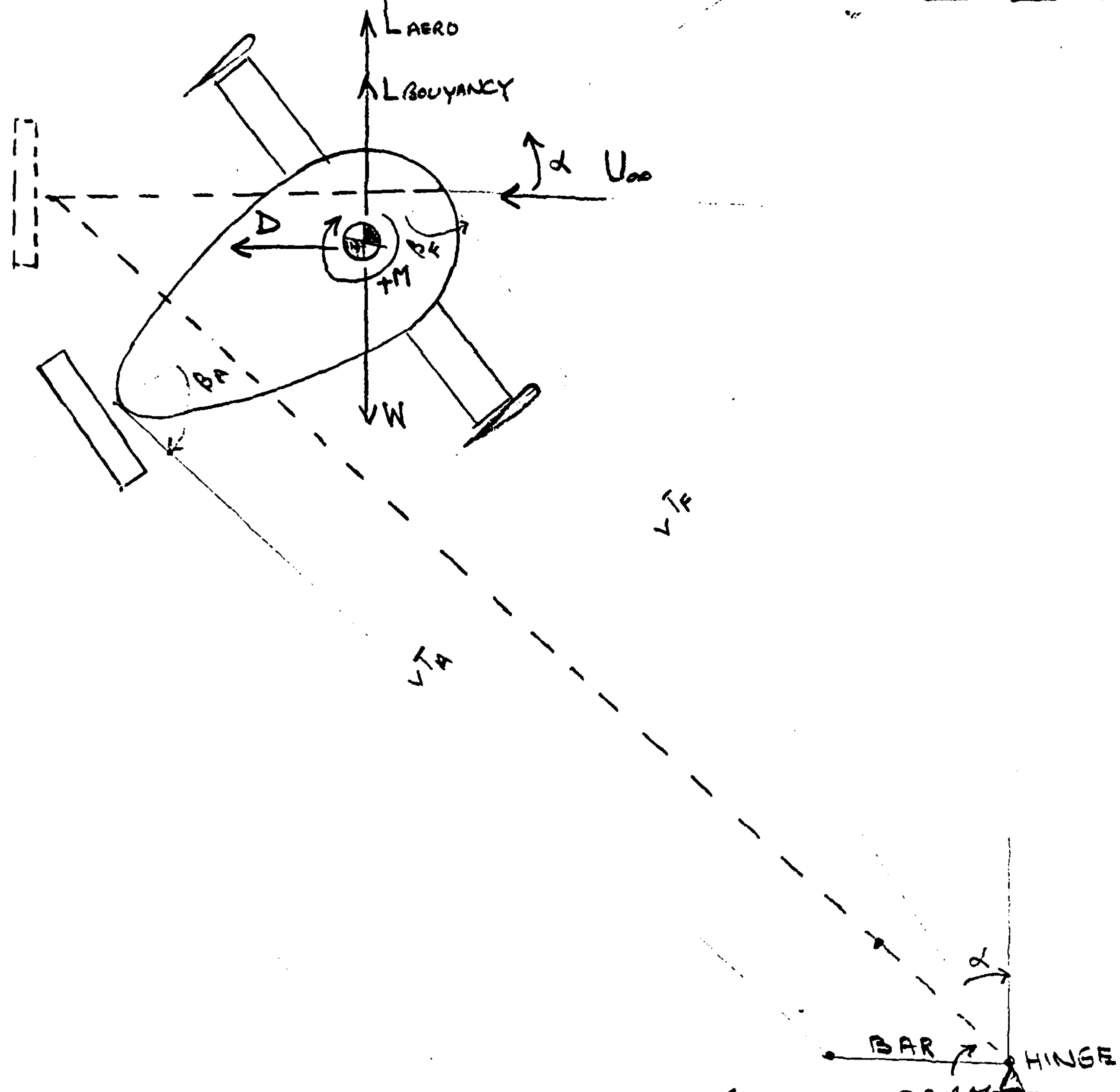
Degrees of Freedom are:

3.1: Vehicle Pitch
3.2: Vehicle Yaw
3.3: Vehicle Vertical Velocity
3.4: Vehicle Lateral Velocity

3.4.3 Model Configuration

The principal model configuration has been fully described in Reference 5. The basic free body diagram is shown in Exhibit 5, following this page.

The CycloCrane model consists of a buoyant centerbody of streamlined shape rotating about an axis that is approximately aligned with the direction of flight. Four rotor blades are rigidly attached to the centerbody and rotate with the centerbody. The tail is annular in shape and attached tc the aerostat's longitudinal structure so as to be free to rotate on that structure. The cab and load are slung below the rotating system.



BASIC FREE BODY DIAGRAM

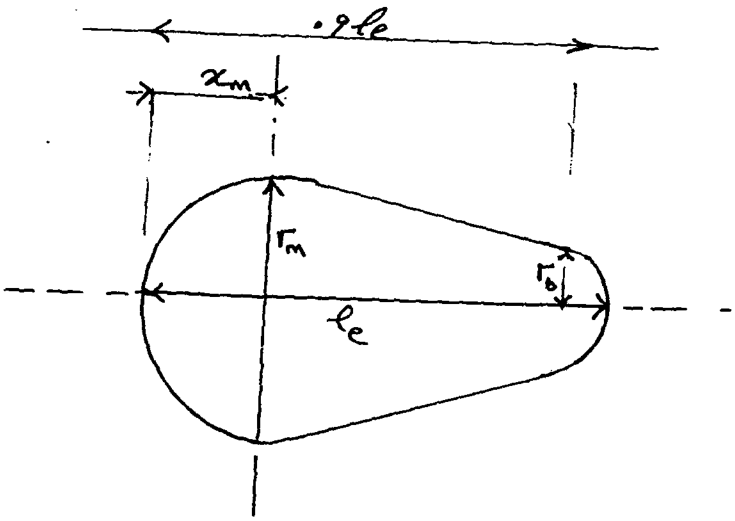
EXHIBIT 5

3.4.4 Proposed Tethering Procedure

The aerodynamic characteristics of the CycloCrane are determined to some extent by the aerodynamic forces acting on the streamlined aerostat centerbody and on the empennage. As in the case of a conventional aircraft fuselage, most of the body contributions are unfavorable, particularly as to stability; hence, tail surfaces are required to at least cancel the unfavorable body effects. The tail area is considered variable in order to examine the sensitivity of the dynamic stability of the vehicle to the tail size in nonrotating and rotating conditions.

3.4.5 Calculation of Drag on X.2 CycloCrane

Aerostat Drag



Envelope Geometry

The normalized profile of the envelope is approximated analytically by the polynomial

$$r = A_{\frac{1}{2}} n^{\frac{1}{2}} + A_1 n + A_2 n^2 \qquad 1$$

where:

$$A_{\frac{1}{2}} = a_{\frac{1}{2}} \, (r_m/le)^{\frac{1}{2}} \qquad 2$$

$$A_1 = a_1 \, (r_m/le)$$

$$A_2 = a_2 \, (r_m/le)^2$$

General character of the profile is determined by specifying the longitudinal positions of (x_m/le) of the maximum radius and the radius (r_b/r_m) at longitudinal position (x_b/le) near the aft end.

$$a_{1/2}/2(x_m/le)^{1/2} + a_1 + 2a_2(x_m/le) = 0$$

$$a_{1/2}\ (x_m/le)^{1/2} + a_1\ (x_m/le) + a_2\ (x_m/le)^2 = 1 \qquad 3$$

$$a_{1/2}\ (x_m/le)^{1/2} + a1\ (x_b/le) + a_2\ (x_b/le)^2 = r_b/r_m$$

Assuming for X.2:

$le = 136$ ft, $r_m = 34$ ft, $x_m = 45.33$ ft
$x_b = 122.4$ ft, $r_b = 18$ ft

Substituting values in Equation 3 and solving for $a_{1/2}$, a_1, and a_2 we get:

$$a_1 = -2.779, \quad a_2 = -.2205, \quad a_{1/2} = 3.3793$$

Substituting values of a_1, $a_{1/2}$, and a_2 in Equation 2 we get:

$$A_1 = -.6944, \quad A_2 = -0.1378, \quad A_{1/2} = 1.6896$$

$$(r_m/le) = (34/136) = .25$$

$$(r_m/le)^{1/2} = .5 \qquad A_1 = a_1\ (r_m/le) = -.6947$$

$$(r_m/le)^2 = .0625 \qquad A_2 = a_2\ (r_m/le)^2 = -.01378$$

$$A_{1/2} = a_{1/2}\ (r_m/le)^{1/2} = 1.6896$$

<u>Aerodynamic Drag on Envelope</u>

Drag area (F_e) on envelope is given by:

$$F_e = .309/(Re_l e^{.2})\ (A_{1/2} le^{1.5} + 1.3A_1 le^2/1.8 +$$
$$1.3A_2 le^3/2.8) + .0176r_m^2$$

$$Re_{le} = leV/Nu = 860759.4937V$$

$$(Re_{le})^{.2} = 15.3807V^{.2}$$

$$.309/15.3807V^{.2} = .02V^{-.2}$$

$(le)^{1.5} = (136)^{1.5} = 1586.0189 \quad A_{\frac{1}{2}}le = 2679.737$

$(le)^2 = (136)^2 = 18496 \quad 1.3/1.8A_1le^2 = -9279.957$

$(le)^3 = (136)^3 = 2525456 \quad 1.3/2.8A_2le^3 = -16093.528$

$.0176r_m^{\,2} = .176(34)^2 = 20.345$

$F_e = .02V^{-.2}[2679.7375 - 9279.957 - 16093.528] + 20.345$

$F_e = -453.8749V^{-.2} + 20.345$

$D_{envelope} = q \times F_e$

$= \frac{1}{2}P_{0V}^{\ 2} \times (F_e)$

$= .001189[20.345 - 453875V^{-.2}] \times V^2$

$D_e = .02419V^2 - .539656V^{1.8}$

$\underline{\underline{D_e = .0242V^2 - .54V^{1.8}}}$

because of sign convention:

$$\boxed{D_e = .54V^{1.8} - .024V^2}$$

Speed (MPH)	Drag (Lbs)
0	0
5	18.3
10	62.75
20	215.70
30	444
40	696.38
60	1522
80	4977.68

Wing Drag

Assuming two wings at one angle of attack and two blades are aligned in such a way that drag is

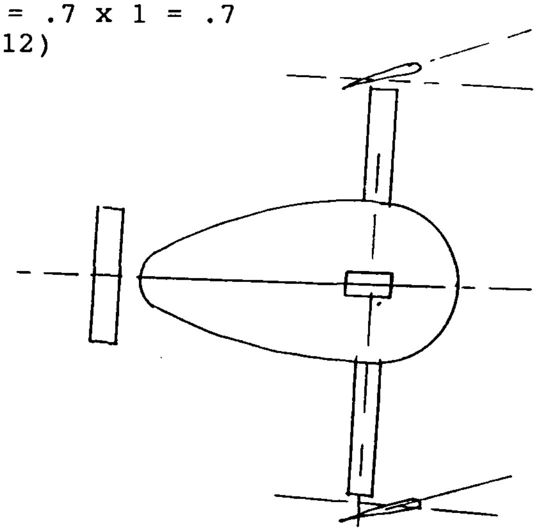
$C_D = C_{DOM} + C_L^{\,2}/(AR \times e) \times .318,$

Assume $AR = 4$

$e = .825$

$C_L = .7 \times I_{MAX} = .7 \times 1 = .7$
(NACA 0012)

$C_{DOM} = .01$



$C_D = .01 + (1 \times .318)/(4 \times .825) = .106$

D_W = Total Drag on wing

$D_W = q \times S_W \times C_{DW}$

$D_W = .001189 \times V^2 \times .106 \times (29 \times 7) \times 2$ (two wings)

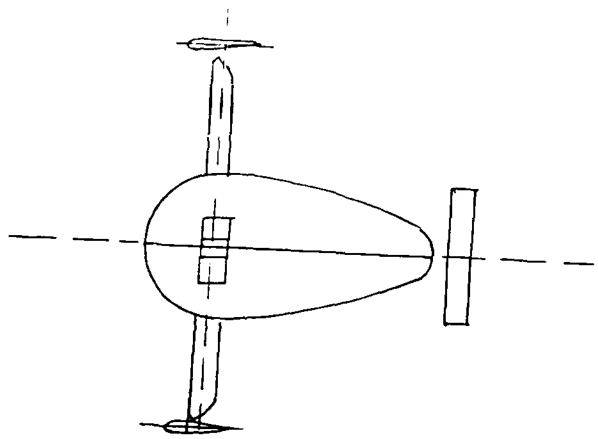
$D_W = .051169V^2 = D_W = .0512V^2$ Lbs (for lift wings)

$D_W = q \times S_W \times C_{DW}$
$= .001189 \times V^2 \times .01 \times (29 \times 7) \times 2$
(for non lifting wings)

$D_W = .00483\ V^2$Lbs (for non lifting wings)

<u>Blade Drag</u>

Assuming two blades at one angle of attack and two blades are aligned in such a way that drag is minimized,



Assume $C_{DB} = .02$ $e = .825$, $AR = 4$

For Blades with Lift

$$C_D = C_{DOM} + 0.318 \times \frac{(C_L^2)}{AR}$$

$$C_D = .02 + \frac{.318 \times 1}{4 \times .825} \qquad C_D = .116$$

$$D_B = .001189 \times V^2 \times .116 \times (26 \times 8) \times 2$$

(for two blades)

$$= 0.0574V^2 \qquad D_B = .0574V^2$$

$$D_B = .001189 \times V^2 \times .02 \times (26.8) \times 2$$

(for non lifting blades)

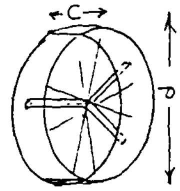
$$D_B = .00989\ V^2 \quad D_B = .0099V^2$$

(for non lifting blades)

Drag on Ring Tail

Total Drag on Tail = $C_D \times S_{REF}$

$$S_{REF} = S_{ring} \times C_{D\ ring} + S_{cables} \times C_{D\ cables} + S_{fin} \times C_{fin}$$



d = 70 ft
c = 10 ft

$S_{ring} = 2 \times C \times D$ Assume $C_{D\ ring} = .02_{ring}$

Total Drag Area $= F_{ring} + F_{cables} + F_{fin}$

$F_{ring} = .02 \times 2 \times 70 \times 10 \times = 28$ $\underline{F_{ring} = 28}$

$F_{cables} = (33.75 \times 36 \times .0104 \times 1.17 + 33.75 \times 36 \times .01562 \times 1.17)$

$= 33.75 \times 36 \times 1.17 \times .026$
$= 36.988 \rightarrow F_{cables} = 36.988$

$F_{fin} = \dfrac{.163}{R_{ecfin}\ 1/5} \times 3 \times S_{fin}$ if $S_{fin} = 10 \times 31.583 = \underline{315.83 ft^2}$

$R_{ecfin} = \dfrac{V \times 10}{n}$ $n = .000158\ \underline{ft^2}/sec$

$R_{ecfin} = 63291.159V \rightarrow$

$F_{fin} = \dfrac{.163}{9.1257 \times V^2} \times 3 \times 315.83 \rightarrow F_{fin} = 16.925\ V^{-2}$

Total drag area of Ring Tail $= 28 + 36.988 + 16.925\ V^2$

<u>Drag on Cables</u>

Total Drag Area = $l \times d$ Sin^3
l = Cable Length
d = Diameter
= Acute Angle of Cable with Aerostat Longitudinal Axes

Total Drag Area

$= 107 \times 8 \times .0208 \times (\text{SIN}37^\circ)^3 \times 4 + 9C \times .0208$
$\quad \times (\text{SIN } 40)^3 \times 4$
$+ \ 32 \times 8 \times .0208\ (\text{SIN}90^\circ)^3$
$= 1.1606 + 7.488 + 4.324$
$= 13.973$

Total Drag Forces On Cables $= q \times F_{cables}$

$$= 1/2\ PV^2F = .00189 \times 13.973V^2$$

Total Force on Cables $= .01661V^2$

<u>Drag on Cabanes</u>

Total Drag Area $= 12 \times .25 \times 4 \times .03 = .36$

Total Drag Force $= \underline{.00189V^2}$

Total Drag Force on Masts $= .0043V^2$

Total Drag Force on CycloCrane

$= (\text{Total Drag})_{aerostat} + (\text{Total Drag})_{wings}$

$+ (\text{Total Drag})_{blades} + (\text{Total Drag})_{tail} +$
$(\text{Total Drag})_{cables} + (\text{Total Drag})_{cabanes}$

$= V^2\ (-.0242 + 0.0512 + .00483 + 0.0574 + 0.0099$
$\quad + 0.0772 + 0.01661 + 00043) + V^{1.8}\ (.54 + 0.02)$

$$\boxed{(\text{Total Drag on X.2}) = .2212V^2 + .56\ V^{1.8}}$$

<u>Speed (MPH)</u>	<u>Drag (Lbs)</u>
0	0
5	32.8
10	118.03
20	435.39
30	936.87
40	1512.47
60	3484.13
80	6017.63

From studies of past experiments and analytical investigations on the dynamic behavior of the CycloCrane in nonrotating and rotating conditions, the following conclusions can be reached:

- There is a marked difference between the rotating and nonrotating aerostat at zero incidence angle; this is possibly attributed to the thickened boundary layer associated with rotation and consequent leeside after-body separation. Studies also show that rotation produces higher effective Reynolds numbers and the rotating data approach C_D = 0.3 at a lower Re than do the nonrotating data.

- In nonrotating conditions, studies show that a Ring Tail ratio of 1 to 1.5 $\left(\frac{\text{Aerostat Dia}}{\text{Ring Tail Dia}}\right)$ on a tethered aerostat would exhibit a stable trim point at an incidence between 5 and 10 degrees.

- The rotation of the CycloCrane forces the load to be supported from the ends, which in turn requires the structure to withstand a much larger bending moment than other conventional aircraft, distributing the load support across the middle.

- In rotational configuration a tail ring size of ratio .5 will produce a statically stable rotating aerostat.

Therefore, it is recommended that for the case of the double line tether CycloCrane (Exhibit 5), a Ring Tail size of 1 to 1.5 be used in the nonrotating configuration. Measured aerodynamics could be expected to seek a trim point yawed 5 to 10 degrees to the relative wind, and displaced laterally a sufficient amount for equilibrium of side force and tether line tensions (lateral component).

Upon first consideration it might seem that tethered mooring in a rotating condition might be a feasible alternative to nonrotating mooring, with the tail size required to be at least equal to or greater than the .5 ratio to provide correct static stability.

Because of the smaller size Ring Tail required (about ratio .5) in rotating configuration as compared to a ratio of about 1 to 1.5 for nonrotating condition, it can be inferred that in rotating condition it is possible to compromise for a more slender aerostat, thus further reducing body drag.

Rotation of the blades in the rotating condition produces large amounts of energized air distributed on the downstream of the aerostat surface; this may contribute to the delay of boundary layer separation on the aft end of the aerostat, thus producing less drag and consequently improving the controllability of the CycloCrane.

More experimental and analytical work is needed to study the downwash effects of the CycloCrane on the aerodynamic characteristics of aerostat, wings, and blades. Special points of interest are possible influences (if any) of downwash on the movement of the turbulent separation point on the aerostat's lee side and its possible influence on Ring Tail size geometry.

Forward thrust produced by rotating blades (propeller effect) and its possible contribution to total forward thrust of the CycloCrane is another case which must be studied.

References have been provided by the following:

Reference 1 H. C. Curtiss, Jr.
Helen Stevenson
DC Associates
Bozman, MD - 21612
November, 1979

Reference 2 William F. Putman
DC Associates
Bozman, MD - 21612
December, 1979

Reference 3 Flight Demonstration of the CycloCrane
AeroLift Inc.
April 29, 1988

Reference 4 U. S. Army Contract
DAAJ002-87-C-0001
February 12, 1988

Reference 5 X.2 Limited Flight Test Plan
AeroLift Inc.
Tillamook, OR
March 15, 1989

4.0 REFURBISHMENT AND MODIFICATION

The refurbishment of the X.2 CycloCrane is essentially complete. There are no major tasks remaining except for adjustment of the aircraft flight controls and its rigging.

The following tasks are required for the completion of modifications:

4.1 "Y" Tail Modification

The design and stress analysis of the "Y" tail is completed and approximately 50% of the detail parts have been fabricated. This item is the major driver in the modification sequence. To expedite this item, a four-man tiger team will focus on this item exclusively during the next few weeks.

4.2 Hydraulic System

This system has been visually inspected and individual components have been checked. An all-up test of the complete system is scheduled for July 23 and August 6.

4.3 Engine Installation and Test

A complete engine installation has been tested for 12 hours of total run time. These tests included runs with the engine in the inverted and knife-edge positions. A rotational test will be run before the aircraft is flown to test the carburation and engine installation under a 4 "g" metric load. Each engine will be tested for 30 minutes prior to installation into the aircraft.

4.4 Avionics Tasks

Bench tests of the avionics systems have been completed. Installation into the aircraft will begin July 17.

5.0 TESTING

The X.2 **LIMITED FLIGHT TEST PLAN**, dated March 15, 1989 was cleared for open publication by the Directorate for Security Review, OASD(PA) on May 10, 1989. Although there has been some slippage in the Flight Readiness Reviews as published and in beginning ground handling and tether tests, the Limited Flight Test Plan is a valid document and will continue to be used by AeroLift as the primary document for planning and executing the limited flight tests.

The status of the systems and subsystems is as follows:

o Propulsion System Testing

As of the end of June, 1989, AeroLift had successfully completed 13.1 hours of testing on the Hirth F-30 engine. We had to modify the Hirth system to insure reliable operation by installing an end bearing on the crank shaft of the engine to compensate for the side pull of the belts required to operate the propeller gear reduction drive. In addition, AeroLift had to encapsulate the propeller shaft in order to prevent flexing of the shaft. We now have a system that we are completely confident in and, as was previously stated, have run for 13.1 hours with little or no difficulty. The engine has successfully run one hour each in the following positions:

- Normal (six o'clock position)
- Inverted (twelve o'clock position)
- Knife-edge (three and nine o'clock positions)

The engine has not been run in the rotating mode as yet; however, this will be accomplished in the next quarter before flight testing. The purpose of the rotational test is to insure that the pressure carburetors will function properly in the rotational mode.

o 36 Foot Model Tests

During this quarter, ten operational tests were performed. For AeroLift identification purposes, these tests were identified as Tests M-1 through M-10. All of these tests are a part of Test T-1 as has been identified in the Limited Flight Test Plan. These tests varied in scope from tail design configuration to single line tether bridle configuration, to crew training. Summary Test Reports are available at AeroLift in Tillamook. These summary test reports will be included as part of the Final Test Report. These tests verified that the Ring Tail with an inverted "Y" insert configuration was the optimum tail configuration that could practically be designed and built within the current cost and schedule constraints. In addition, it was verified that tethering in the "plus" configuration rather than the "X" position of the aircraft is again the optimum position for the aircraft while at a tether. Additional ground handling exercises are anticipated during the next quarter.

PROJECT

FIRST DEFENSE

EXHIBIT 1

PROBLEMS

- NO DEEP/EARLY DETECTION
- INCOMPLETE PICKET LINE AT BORDERS
- FEW CAPABILITIES IN OTHER COUNTRIES
- COORDINATION OF REACTION FORCES
- LIMITED FUNDS

KEY QUESTIONS:

WHERE, AND WITH WHAT, TO ATTACK DRUG SMUGGLERS' SYSTEM?

THE SOUTHEAST BORDER DILEMMA

- DRUG SMUGGLERS USE MARITIME AND AIRBORNE TRANSPORTATION
  - NO EFFECTIVE CONTROL AT POINT OF ORIGIN
  - U.S. HAS 96,000 MILES OF BORDER
  - DRUG SMUGGLERS FLY ESTIMATED 3,000 FLIGHTS PER YEAR
- SURPRISE AND VERSATILITY WITH SMUGGLERS
  - MULTIPLE ROUTES/VEHICLES
  - COASTAL DENSITY
  - OPTION TO ABORT AT ANY TIME

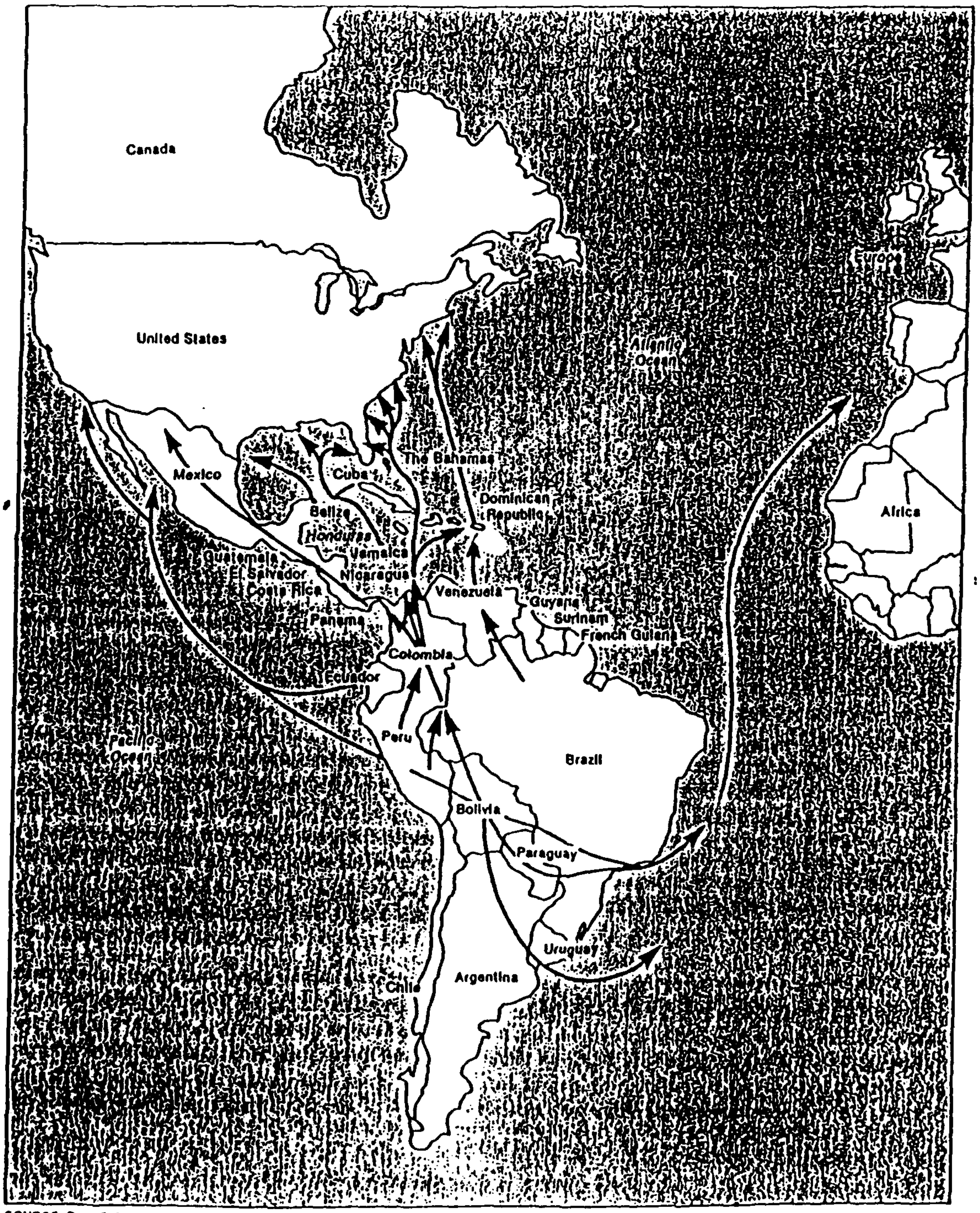
LONG-RANGE SURVEILLANCE REQUIREMENT

- DETECT/SORT/TRACK SUSPECT PRIOR TO HIS REACHING TRAFFIC DENSITY AT BORDERS
- HIGH ENDURANCE, MOBILE WITH LARGE AREA AIR/SURFACE SEARCH RADAR CAPABILITY
- OPERATE FROM SINGLE BASE TO ENHANCE OPSEC
- DEPLOY WITH OWN SUPPORT
- PROVIDE CREW ENVIRONMENT

MISSION STATEMENT

- DETECT LOW-ALTITUDE (<1,000 FEET), SLOW-FLYING (<200 KNOTS) AIRCRAFT WITHIN 12 MILES OF COAST OF COLOMBIA AND TRACK TO SOUTHERN U.S.
- ON ORDER, PROVIDE PERIODIC ELECTRONIC SURVEILLANCE OF SELECTED DEPARTURE POINTS IN NORTHERN TIER OF SOUTH AMERICA

Figure 8.—Cocaine Smuggling Routes From Latin America to the United States and Europe

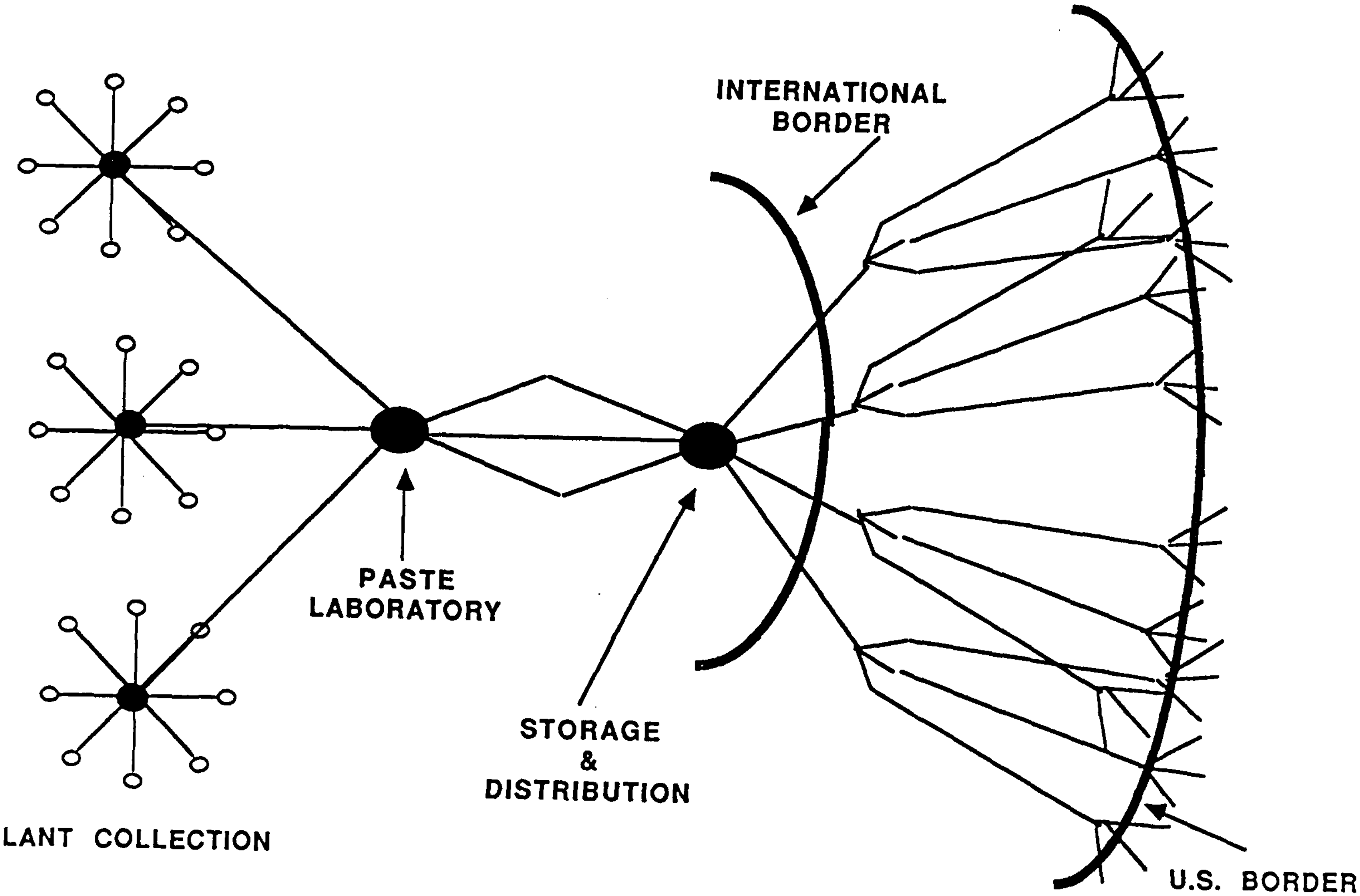


SOURCE: Drug Enforcement Administration.

FIRST DEFENSE CONCEPT

DEPLOY A MOBILE, FORWARD OPERATIONS BASE AT SEA OFF THE COAST OF COLOMBIA WITH OPERATIONAL AIR/SEA INTELLIGENCE COLLECTORS TO IDENTIFY SUSPECT AIRCRAFT AND SHIPS EARLY, AND SORT AND TRACK SUSPECTS FOR HANDOFF TO U.S. CLOSE-IN TRACKING AND REACTION FORCES

THE AIR TRANSPORT NETWORK



CAPABILITIES OF THE FORWARD AT-SEA OPERATIONS BASE

- SEMI-SUBMERSIBLE OFFSHORE PLATFORMS
- SHIP BASE SIMILAR TO U.S. ARMY'S SASS
- LAND-BASED
  - EXISTING U.S. BASE
  - LEASED FOREIGN FACILITY
- COMBINATION

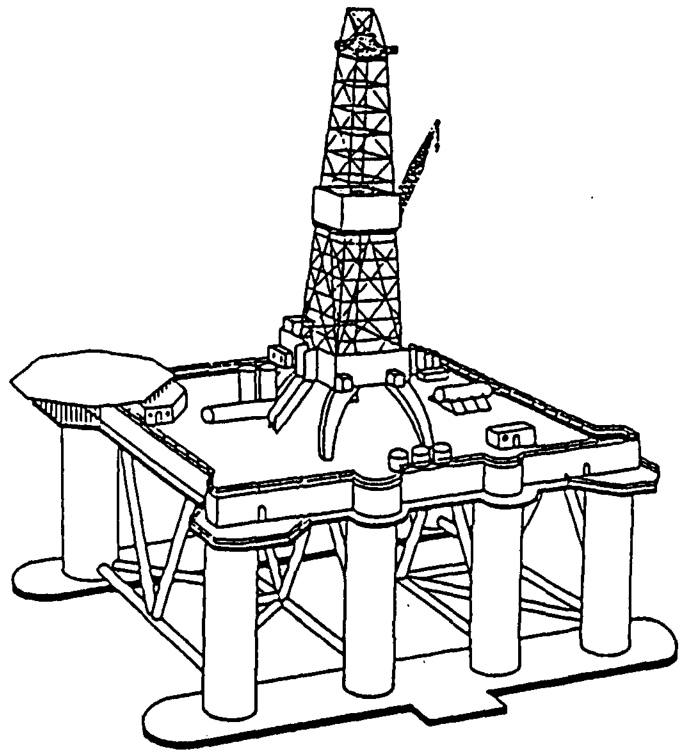
OFFSHORE PLATFORMS

- EXISTING SEMI-SUBMERSIBLE PLATFORMS
  - LARGE NUMBERS AVAILABLE
  - \$400 - \$500 K MOBILIZATION COSTS
  - \$12 K/DAY TURNKEY/HOTEL OPERATION
  - \$3 K/DAY TO MAINTAIN IN 24 HOUR READY STATUS
- TOWED AT 10 KNOTS
- MAX DEPTH FOR ANCHORING - 1,500 FEET
- C^3 I, LOGISTICS AND SPECIAL OPERATIONS USES:
  - RADARS
  - RPV
  - INTEL
  - RELAY
  - PLANNING CELLS
  - AIRSHIP
- LAUNCH PLATFORMS FOR MISSILES?

TABO

MODULAR PLATFORM CONCEPT

SEMI-SUBMERSIBLE PLATFORM



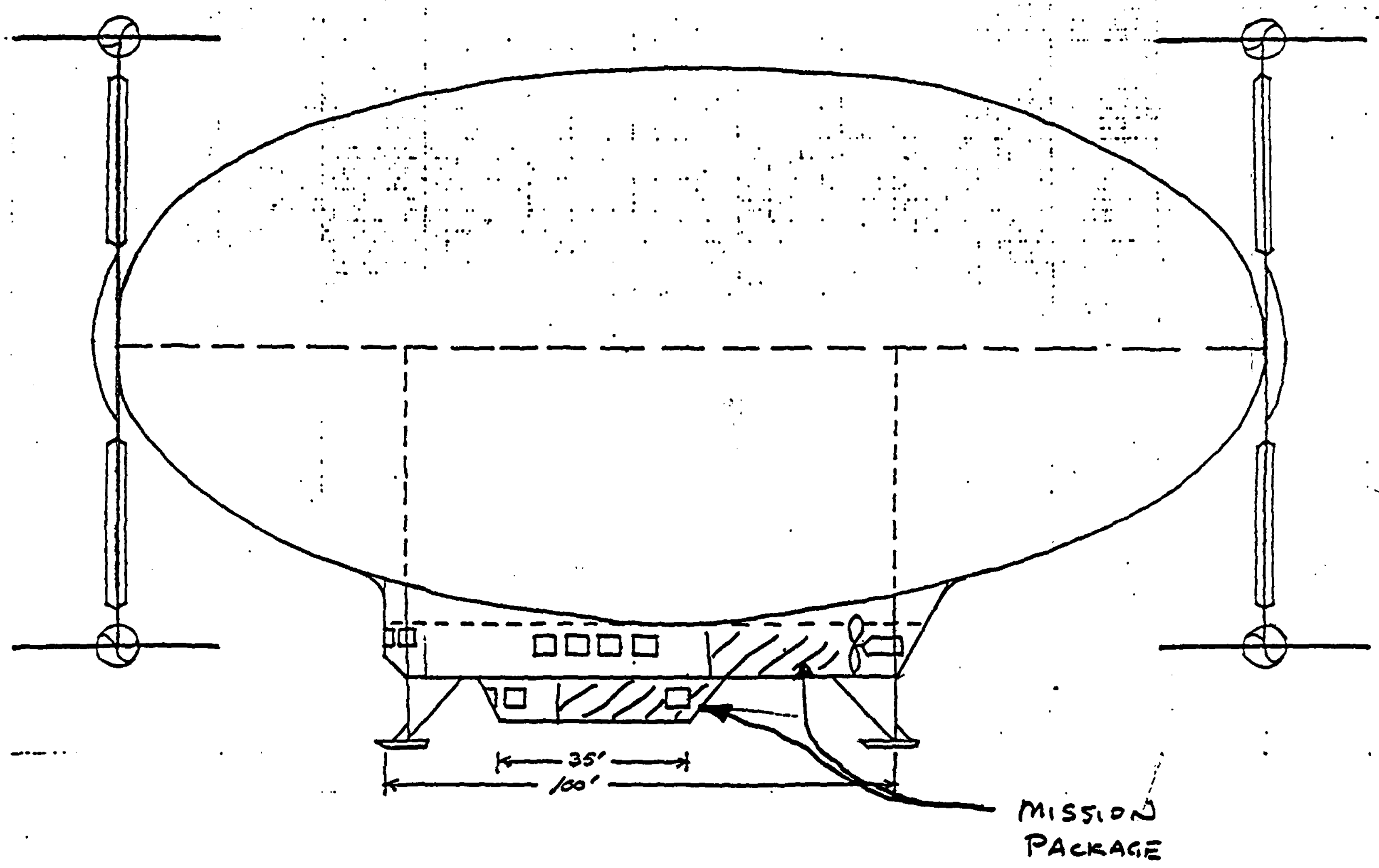
THE *BDM* CORPORATION

OPERATING PARAMETERS OF X-10

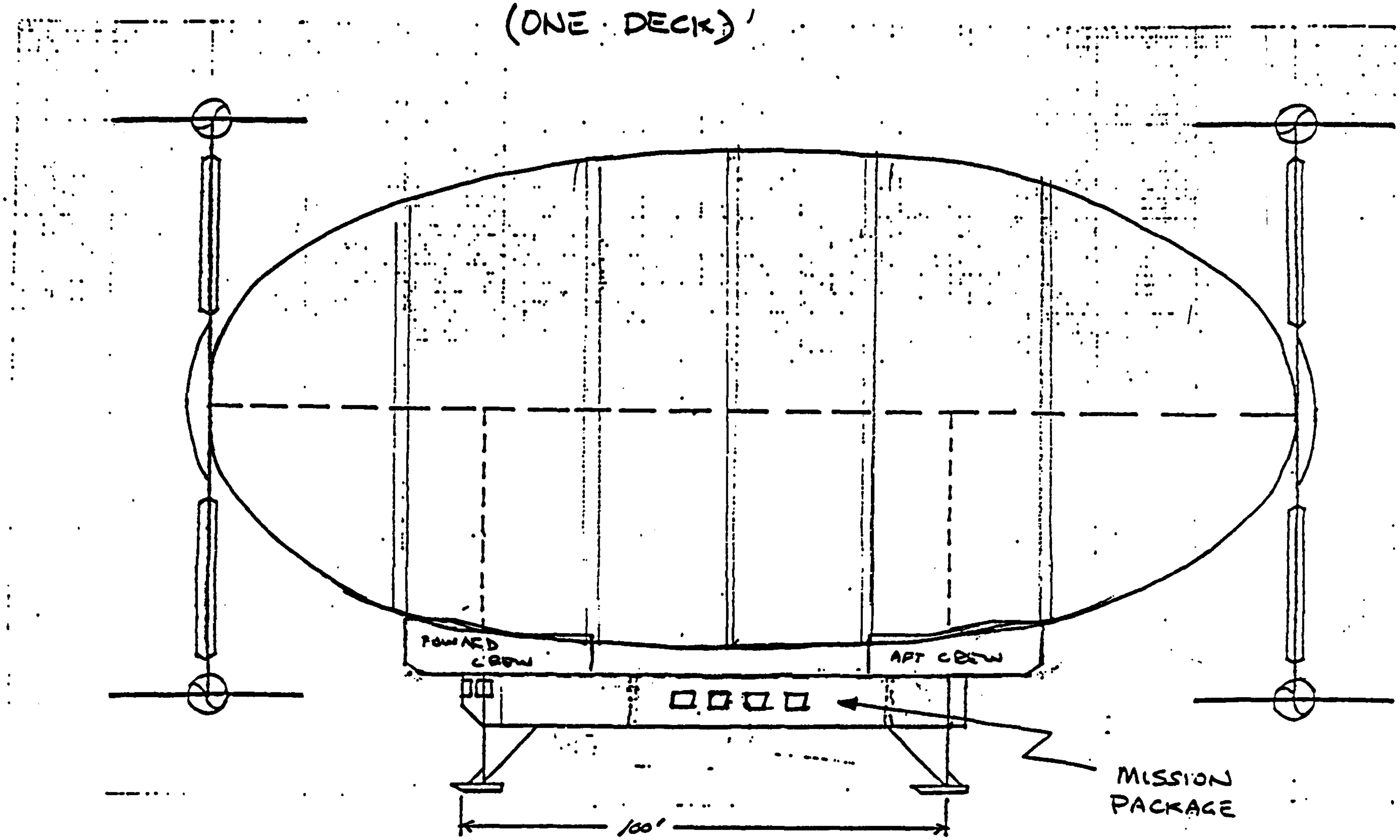
- WIND $\leqq$ 40 MPH (GUSTS TO 90 MPH)*
- ALTITUDE $\leqq$ 10,000 FEET
- CARRY 20,000 LB OF FUEL & MISSION PACKAGE
- DAY/NIGHT OPERATIONS
- 30-DAY MISSION WITH IN-FLIGHT REFUELING
- FREQUENCY OF REFUELING DEPENDS ON FUEL/ MISSION PACKAGE TRADEOFFS

*Estimated

CYCLOCRANE FOR SURVEILLANCE
(TWO DECKS)



Y. IC C. ILLURMNE FOR SURVEILLANCE
(ONE DECK)



SENSOR PACKAGE FOR EACH CYCLOCRANE

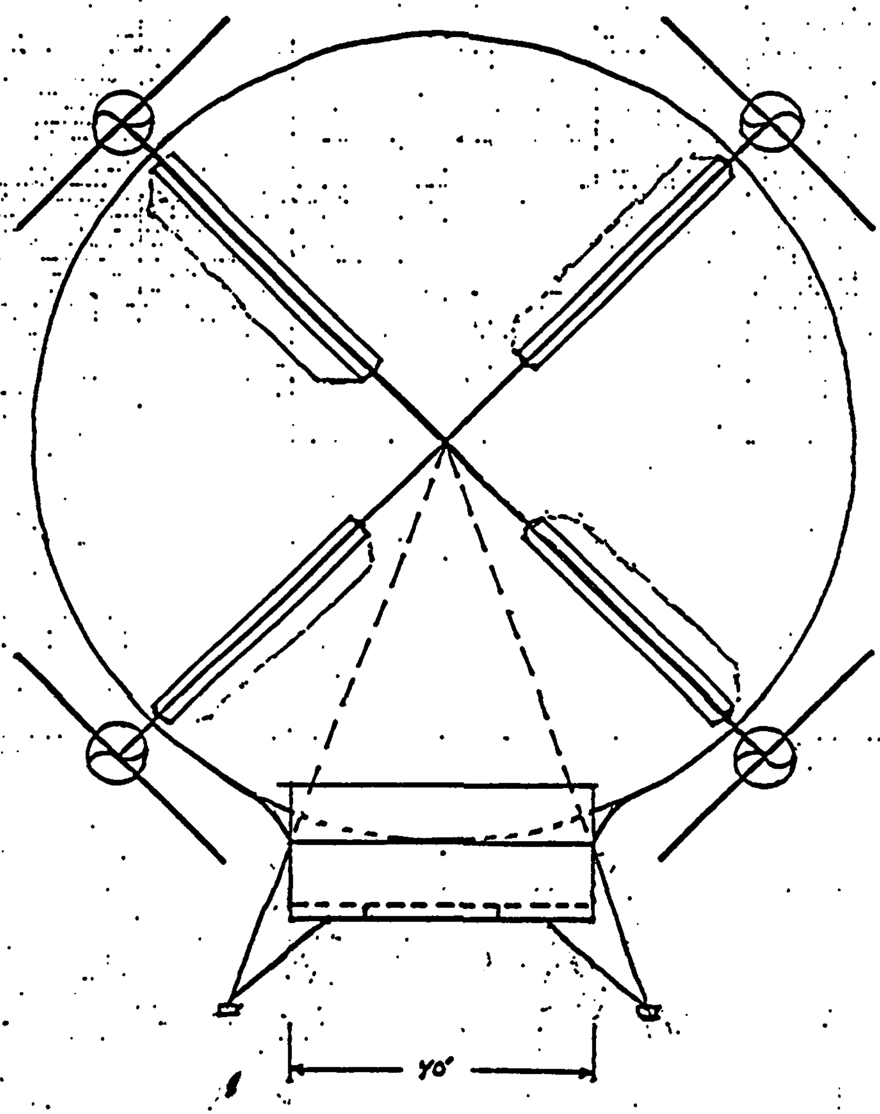
- AIR SEARCH RADAR*
- SURFACE SEARCH RADAR*
- UHF/VHF INTERCEPT COMMS
- FLIR/LLLTV
- LONG-RANGE OPTICS CAMERA
- SECURE COMMS LINKS TO BASE

*Could be single radar

CAPABILITIES OF THE FORWARD AT-SEA OPERATIONS BASE

- LAUNCH AND RECOVER
  - CYCLOCRANE WITH MULTIPLE SENSORS FOR LONG DURATIONS
  - SMALL, HIGH-SPEED PATROL BOAT FOR SURFACE SURVEILLANCE/INTERDICTION
- AEROSTAT W/AIR SEARCH RADAR
- SECURE COMMAND, CONTROL, COMMO
- ANALYTICAL ELEMENT
- ORGANIC MAINTENANCE FOR BILLETING/MESSING AND OPERATIONAL SPACE

IVI-1U CYCLOCRANE FOR SURVEILLANCE (FRONT VIEW)



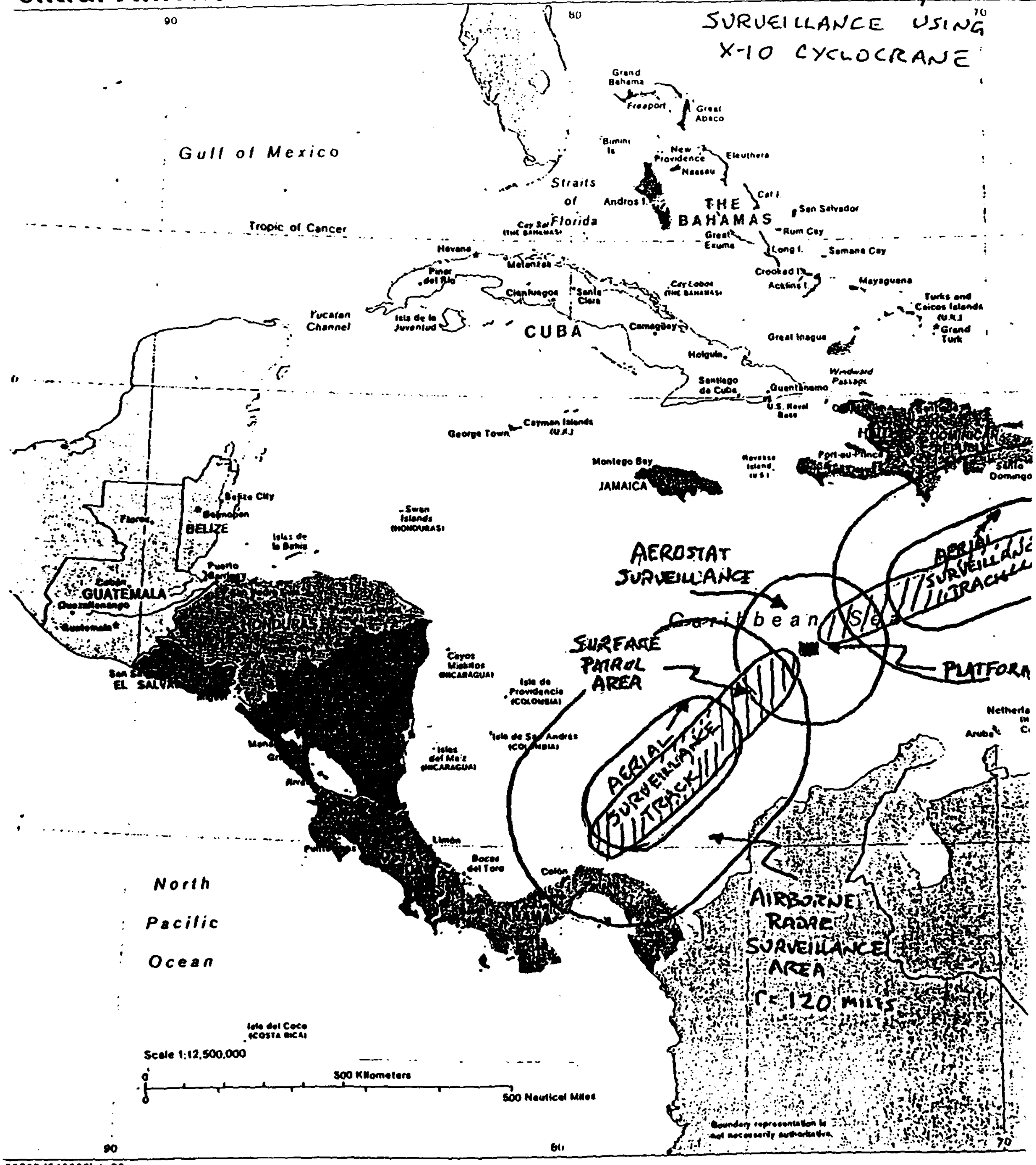
OPERATIONAL AREA AND ORBIT SELECTION

$\boxed{\text{WOULD BE PLANNED BASED ON}}$

- AVAILABLE INTELLIGENCE
- TRAFFICKING PROFILES AND PATTERNS
- TRACKING CONTINUITY
- LOCATION OF AIRBORNE AND LAND-BASED REACTION FORCES

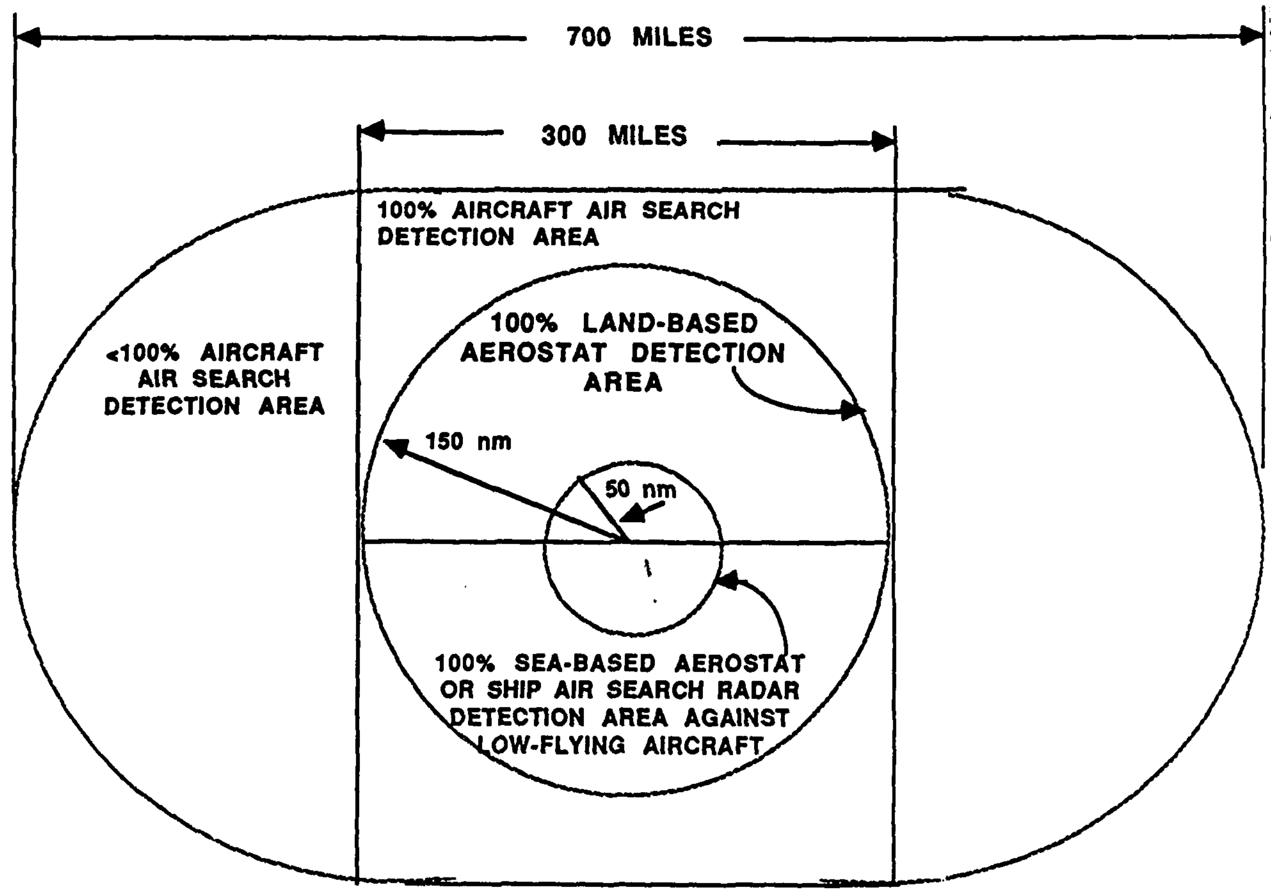
TYPICAL OPERATIONAL CONCEPT FOR AIR/SEA SURVEILLANCE USING X-10 CYCLOCRANE

entral America and the Caribbean



05702 (545527) 4-83

ESTIMATED DETECTION RANGES OF SEVERAL RADAR PLATFORMS



OPERATIONAL ADVANTAGES

- NEED ONLY ONE SEA-BASED PLATFORM TO IMPLEMENT
- SURVEILLANCE IS FLEXIBLE/VERSATILE
- CAN PURSUE AT 90 MPH
- AVOID SEVERE WEATHER
- SURVEIL SURFACE INTERCEPTIONS
- LOWER COSTS
- LONGEST ENDURANCE OF OPTIONS
- IMPROVES OPSEC OF SURVEILLANCE SHIPS

PROPOSAL

IMPLEMENT 3-PHASED PROGRAM

- PHASE I (NEAR-TERM): USE X-2 PROTOTYPE AS TEST PROGRAM IN OPERATIONAL ENVIRONMENT

- PHASE II (MID-TERM): CONTRACT TO LEASE TWO CYCLOCRANES:

  BUILD IN 18 MONTHS

  COST FOR 10 TON/10,000 FT LONG ENDURANCE:

  — $8-10 MILLION EACH

  WILL BUILD TO LEASE

  — NO USG MANPOWER DRAIN

  SENSORS ADDITIONAL

- PHASE III (LONG-TERM): BASED ON PROVEN CAPABILITY, EXPAND USE OF CYCLOCRANES

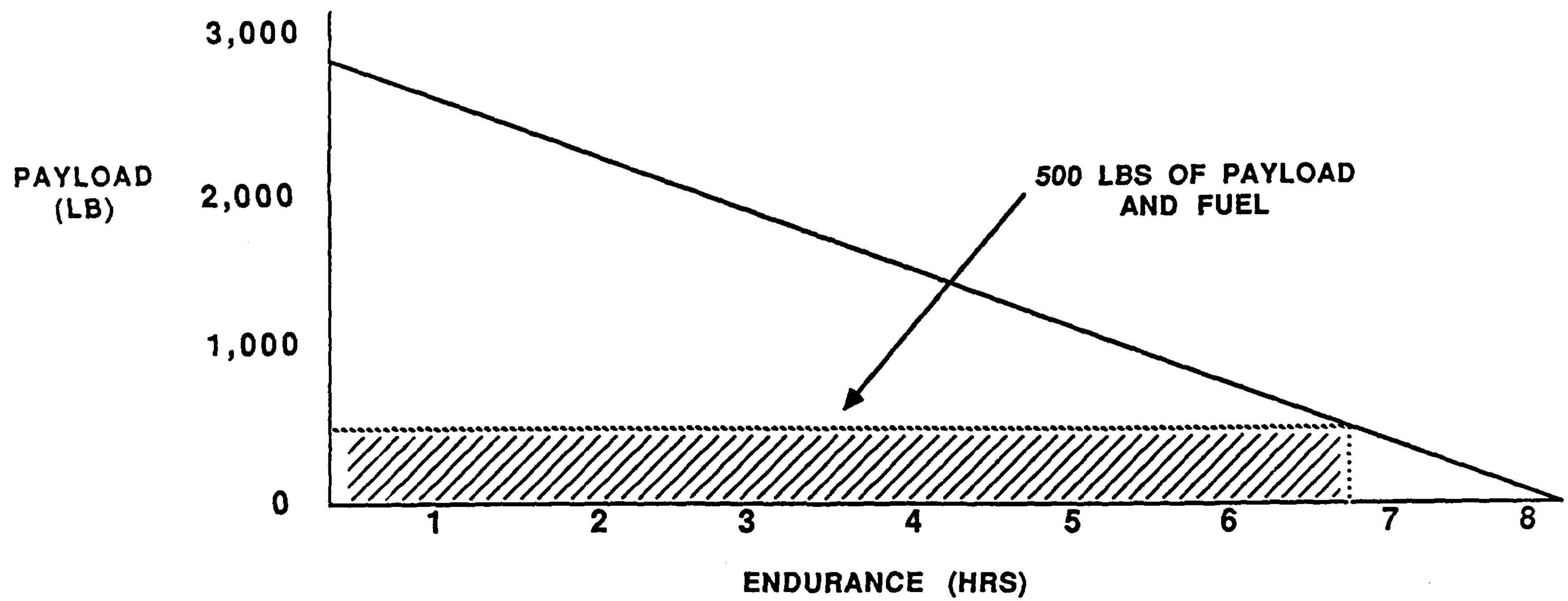
OPERATING PARAMETERS OF X-2

- WIND $\leqq$ 30 MPH (GUSTS TO 40 MPH)*
- ALTITUDE $\leqq$ 4,000 FEET
- 4 X 6 HR EACH FLIGHTS PER WEEK (100 WEEKS PER YEAR)
- GROUND MAINTENANCE SPACE AVAILABLE
- VFR ONLY**
- DAYLIGHT HOURS ONLY**
- NO DATA ACQUISITION PROVIDED BY AEROLIFT**

* ESTIMATED

** IFR, NIGHT FLIGHT AND DATA ACQUISITION CAN BE ACCOMPLISHED WITH AVIONICS AND INSTRUMENTATION PACKAGES FURNISHED GFE

X-2 CYCLOCRANE
PAYLOAD VS ENDURANCE



RISKS

- UNCERTAINTY OF NEW TECHNOLOGY
- AIR PURSUIT NOT POSSIBLE FOR LONG DURATION
- SLOWER TO RELOCATE TO NEW SURVEILLANCE AREA

FLIGHT HRS X VARIABLE COSTS + FIXED COSTS = COST PER FLIGHT HOUR

ESTIMATED FIXED COSTS

ASSUMPTIONS: 2 YRS OF OPERATION, 1200 FLYING HOURS PER YEAR

TRANSPORTATION (X-2 & GROUND EQPT)	$115,000	
PER DIEM (14 X $50 PER DAY)	504,000	
FLT CREW & MGR SALARY	490,000	
GROUND CREW SALARY	800,000*	
MAINTENANCE EQUIPMENT	130,000	
	$2,039,000	= $850/FLT HR

ESTIMATED VARIABLE COSTS

EQUIPMENT (X-2 + SPARES):

PROPULSION SYSTEM	$82,000	
HYDRAULICS	25,000	
STALK REPAIR	20,000	
TELEMETRY REPAIR (REPLACEMENT)	140,000*	
AEROSTAT REPAIR	20,000	
CABLES (REPAIR/REPLACE)	11,000	
HELIUM REPLACEMENT	144,000*	
HELIUM PURIFICATION	116,000	
POL	72,000	
	$630,000	= $525/FLT HR
	+ 20% PROFIT	= $630/FLT HR

TOTAL: $1,480/FLT HR (W/PROFIT)

* Probably a high estimate

PROCUREMENT/MAINTENANCE ADVANTAGES

- LOW ACQUISITION COSTS
- LOW OPERATING COSTS

COST COMPARISONS OF AVAILABLE ALTERNATIVES

SYSTEM	ESTIMATED ACQUISITION ($)	HOURLY O&M ($)
E-2C	45M	1655
P-3	90M	2365
C-130	90M	2035
LTA	75M*	750
AEROSTAT	18-20M	500
CYCLOCRANE	8-10M*	525

* DOES NOT INCLUDE SENSORS

RECOMMENDATIONS

- START TEST NOW USING X-2 AS TESTING PLATFORM -- BEGIN W/RADAR
- PROVIDE CONTRACT FOR 2- TO 5-YEAR LEASE FOR 2 CYCLOCRANES IN FY90 TO BE OPERATIONAL IN FY91

EXHIBIT 2

DARPA_10_TON
Double_rotor
Turboprop_engine

TITLE PAGE
Wed May 31 08:38:58 1989

number of stages =	2.00	days of operation =	0.40
number of crew =	2.00	total hours =	9.60
area cabin =	35.00	Cd cab =	0.30
area payload =	28.30	Cd payload =	0.60
AR blade =	4.00	Cd blade =	0.02
AR wing =	4.00	Cd wing =	0.01
inital lift =	1,696.17	final lift =	-1,696.70
FINENESS RATIO =	2.00		
WING SPAN/ENV. DIA. =	0.50	BLADE SPAN/ENV. DIA. =	0.50
AEROSTAT VOLUME =	968,805.43	PERCENT BALLONET =	0.20
AEROSTAT LENGTH =	194.88	BALLAST =	OFF
AEROSTAT RADIUS =	48.72	AEROSTAT DIAMETER =	97.44
SPAN BLADE =	48.72	AREA BLADE =	593.41
SPAN WING =	48.72	AREA WING =	593.41
DIAMETER TAIL =	0.00	AREA TAIL =	0.00

DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

STAGE NUMBER	FLIGHT MODE	VELOCITY FORWARD	VELOCITY VERTICAL	STAGE TIME	STAGE ALTITUDE	STAGE PAYLOAD
1.00	cruise	73.30	0.00	9.45	3500.00	20000.00
2.00	cruise	102.66	0.00	0.15	3500.00	20000.00

DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

TABLE B.1 (Continued)
DARPA_10_TON
Double_rotor
Turboprop_engine

WEIGHT SUMMARY
Wed May 31 08:38:59 1989

stage =	1.00	Hours =	9.45
Altitude =	3,500.00	Payload =	20,000.00
Fineness ratio =	2.00	Ballonet design alt. =	3,500.00
Wing span/Env. dia. =	0.50	Blade span/Env. dia. =	0.50
ARwing =	4.00	ARblade =	4.00
Wing Area =	593.41	Blade Area =	593.41
Wing Span =	48.72	Blade Span =	48.72

EROSTAT DIAMETER (DIAenv): 97
EROSTAT VOLUME (VOLenv): 968805

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IXED WEIGHTS	
Controls, Actuators, Wiring	653.28
Bearings	300.00
Cab weight	3,000.00
Handling Cables, Equip.	0.00
Contingency	0.00
TRUCTURAL WEIGHTS	
Aerostat, Ballonet, and Soft Structures	8,811.83
External Cables	275.60
Internal Structure	4,993.07
Blade Columns	1,188.76
WINGS	1,306.56
ADES	6,191.65
NGINES, NACELLES, PROPS	2,785.01
TAIL	0.00
JEL SYSTEM	356.25

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JTAL DRY WEIGHT	29,862.02
FUEL	3,562.51
AYLOAD	20,000.00
CREW WEIGHT	400.00
JTAL WEIGHT	53,824.53

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JOYANCY	52,128.83
MAX. AERODYNAMIC LIFT REQUIRED FOR HOVER	3,202.78

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TABLE B.1 (Continued)
DARPA_10_TON
Double_rotor
Turboprop_engine

HOVER POWER
Wed May 31 08:39:00 1989

stage =	1.00	Hours =	9.45
Altitude =	3,500.00	Payload =	20,000.00
Fineness ratio =	2.00	Ballonet design alt. =	3,500.00
Wing span/Env. dia. =	0.50	Blade span/Env. dia. =	0.50
ARwing =	4.00	ARblade =	4.00
Wing Area =	593.41	Blade Area =	593.41
Wing Span =	48.72	Blade Span =	48.72

EROSTAT DIAMETER (DIAenv): 97
EROSTAT VOLUME (VOLenv): 968805

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^ERODYNAMIC LIFT	
Maximum	3,202.78
WING VELOCITY (ft/sec)	
Maximum	50.41
SHP (Induced Hover)	
Maximum	159.15
SHP (Aerostat Profile)	
Maximum	3.72
SHP (Wing Profile)	
Maximum	38.34
HP (Blade Profile)	
Maximum	20.54
HP (Long. Cable Profile)	
Maximum	0.00
HP (Rot. Cable Profile)	
Maximum	2.25
HP (Nacelle Profile)	
Maximum	4.43

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TOTAL HOVER SHP	
Maximum Required For Hover	228.42
Maximum Available	2,142.31

TABLE B.1 (Continued)
DARPA_10_TON
Double_rotor
Turboprop_engine

CRUISE POWER
Wed May 31 08:39:00 1989

stage =	1.00	Hours =	9.45
Altitude =	3,500.00	Payload =	20,000.00
Fineness ratio =	2.00	Ballonet design alt. =	3,500.00
Wing span/Env. dia. =	0.50	Blade span/Env. dia. =	0.50
ARwing =	4.00	ARblade =	4.00
Wing Area =	593.41	Blade Area =	593.41
Wing Span =	48.72	Blade Span =	48.72

EROSTAT DIAMETER (DIAenv): 97
EROSTAT VOLUME (VOLenv): 968805

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	WING	BLADE	TAIL	ENVELOPE
L	0.042	0.046	0.017	0.000
% LIFT	46.977	51.936	0.000	1.087
CDI	0.000	0.000	0.000	0.000
I	2.344	2.591	0.000	0.054
LPHA	0.381	0.422	0.168	0.168

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RUISE SPEED

True Airspeed (ft/sec)	73.30

RUISE SHP REQUIREMENTS

SHP (Induced lift)	1.11
SHP (Aerostat Profile)	341.77
SHP (Wing Profile)	67.36
SHP (Blade Profile)	134.73
SHP (Long. Cable Profile)	0.00
SHP (Rot. Cable Profile)	78.23
SHP (Nacelle Profile)	13.62
SHP (Cabin Profile)	14.90
SHP (Tail Profile)	0.00
SHP (Payload Profile)	24.34
SHP (Sling Cable Profile)	0.00
SHP (Sled Drag Profile)	0.00

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OTAL CRUISE SHP REQUIRED 676.07

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uel Wt. Burned For Stage 3,259.35

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Fuel Wt. Total at beginning of stage 3,562.51

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allast Wt. at end of stage 0.00
allast Wt. at beginning of stage 0.00

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otal Wt. at beginning of stage 53,824.53

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Buoyancy @ Altitude 52,128.83

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nitial Aerodynamic Lift 1,696.17
Final Aerodynamic Lift -1,563.18

TABLE B.1 (Continued)
DARPA_10_TON
Double_rotor
Turboprop_engine

CRUISE POWER
Wed May 31 08:39:01 1989

stage =	2.00	Hours =	0.15
Altitude =	3,500.00	Payload =	20,000.00
Fineness ratio =	2.00	Ballonet design alt. =	3,500.00
Wing span/Env. dia. =	0.50	Blade span/Env. dia. =	0.50
ARwing =	4.00	ARblade =	4.00
Wing Area =	593.41	Blade Area =	593.41
Wing Span =	48.72	Blade Span =	48.72

EROSTAT DIAMETER (DIAenv): 97
EROSTAT VOLUME (VOLenv): 968805

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	WING	BLADE	TAIL	ENVELOPE
L	-0.025	-0.028	-0.010	-0.000
% LIFT	46.977	51.936	0.000	1.087
CDI	0.000	0.000	0.000	0.000
I	1.658	1.833	0.000	0.038
LPHA	-0.229	-0.253	-0.101	-0.101

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RUISE SPEED

True Airspeed (ft/sec)	102.66

RUISE SHP REQUIREMENTS

SHP (Induced lift)	1.10
SHP (Aerostat Profile)	938.93
SHP (Wing Profile)	185.06
SHP (Blade Profile)	370.12
SHP (Long. Cable Profile)	0.00
SHP (Rot. Cable Profile)	214.92
SHP (Nacelle Profile)	37.42
SHP (Cabin Profile)	40.93
SHP (Tail Profile)	0.00
SHP (Payload Profile)	73.42
SHP (Sling Cable Profile)	0.00
SHP (Sled Drag Profile)	0.00

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TAL CRUISE SHP REQUIRED	1,861.90

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Fuel Wt. Burned For Stage	133.52

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Fuel Wt. Total at beginning of stage	303.16

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allast Wt. at end of stage	0.00
allast Wt. at beginning of stage	0.00

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otal Wt. at beginning of stage	50,565.18

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Buoyancy @ Altitude	52,128.83

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itial Aerodynamic Lift	-1,563.18
Final Aerodynamic Lift	-1,696.70

EXHIBIT 3

ARMY_CORPS_REAR_AREA_SURVEILLANCE_MISSION
Single_rotor
Four_stroke

TITLE PAGE
Fri Jul 28 12:41:08 1989

number of stages =	7.00	days of operation =	1.04
number of crew =	10.00	total hours =	25.00
area cabin =	35.00	Cd cab =	0.30
area payload =	120.00	Cd payload =	0.60
AR blade =	4.00	Cd blade =	0.02
AR wing =	4.00	Cd wing =	0.01
inital lift =	20,195.73	final lift =	-20,191.86
FINENESS RATIO =	2.00		
JING SPAN/ENV. DIA. =	0.50	BLADE SPAN/ENV. DIA. =	0.50
AEROSTAT VOLUME =	3,077,561.28	PERCENT BALLONET =	0.31
AEROSTAT LENGTH =	286.48	BALLAST =	ON
AEROSTAT RADIUS =	71.62	AEROSTAT DIAMETER =	143.24
SPAN BLADE =	71.62	AREA BLADE =	1,282.33
SPAN WING =	71.62	AREA WING =	1,282.33
DIAMETER TAIL =	127.48	AREA TAIL =	4,062.92

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STAGE NUMBER	FLIGHT MODE	VELOCITY FORWARD	VELOCITY VERTICAL	STAGE TIME	STAGE ALTITUDE	STAGE PAYLOAD
1.00	climb	101.34	5.55	0.25	5000.00	18550.00
2.00	cruise	101.34	0.00	4.00	5000.00	18550.00
3.00	climb	101.34	5.55	0.25	10000.00	18550.00
4.00	cruise	101.34	0.00	16.00	10000.00	18550.00
5.00	descend	101.34	-5.55	0.25	5000.00	18550.00
6.00	cruise	101.34	0.00	4.00	5000.00	18550.00
7.00	descend	101.34	-5.55	0.25	0.00	18550.00

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TABLE B.1 (Continued)
ARMY_CORPS_REAR_AREA_SURVEILLANCE_MISSION
Single_rotor
Four_stroke

WEIGHT SUMMARY
Fri Jul 28 12:41:09 1989

stage =	1.00	Hours =	0.25
Altitude =	5,000.00	Payload =	18,550.00
Fineness ratio =	2.00	Ballonet design alt. =	10,000.00
Wing span/Env. dia. =	0.50	Blade span/Env. dia. =	0.50
ARwing =	4.00	ARblade =	4.00
Wing Area =	1,282.33	Blade Area =	1,282.33
Wing Span =	71.62	Blade Span =	71.62

AEROSTAT DIAMETER (DIAenv): 143
EROSTAT VOLUME (VOLenv): 3077561

FIXED WEIGHTS	
Controls, Actuators, Wiring	1,598.39
Bearings	285.50
Cab weight	3,000.00
Handling Cables, Equip.	0.00
Contingency	0.00
STRUCTURAL WEIGHTS	
Aerostat, Ballonet, and Soft Structures	18,994.73
External Cables	4,918.84
Internal Structure	23,316.40
Blade Columns	1,747.51
WINGS	3,196.78
LADES	7,475.34
ENGINES, NACELLES, PROPS	14,562.29
AIL	14,515.41
FUEL SYSTEM	4,240.70

TOTAL DRY WEIGHT	97,851.90
UEL	42,406.97
PAYLOAD	18,550.00
CREW WEIGHT	5,000.00
OTAL WEIGHT	163,808.87

UOYANCY	143,611.65
MAX. AERODYNAMIC LIFT REQUIRED FOR HOVER	24,346.35

TABLE B.1 (Continued)
ARMY_CORPS_REAR_AREA_SURVEILLANCE_MISSION
Single_rotor
Four_stroke

HOVER POWER
Fri Jul 28 12:41:10 1989

stage =	1.00	Hours =	0.25
Altitude =	5,000.00	Payload =	18,550.00
Fineness ratio =	2.00	Ballonet design alt. =	10,000.00
Wing span/Env. dia. =	0.50	Blade span/Env. dia. =	0.50
ARwing =	4.00	ARblade =	4.00
Wing Area =	1,282.33	Blade Area =	1,282.33
Wing Span =	71.62	Blade Span =	71.62

AEROSTAT DIAMETER (DIAenv): 143
EROSTAT VOLUME (VOLenv): 3077561

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AERODYNAMIC LIFT	
Maximum	24,346.35
WING VELOCITY (ft/sec)	
Maximum	94.54
HP (Induced Hover)	
Maximum	2,687.81
HP (Aerostat Profile)	
Maximum	43.31
HP (Wing Profile)	
Maximum	273.30
HP (Blade Profile)	
Maximum	146.41
HP (Long. Cable Profile)	
Maximum	78.07
SHP (Rot. Cable Profile)	
Maximum	10.90
SHP (Nacelle Profile)	
Maximum	29.23

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OTAL HOVER SHP	
Maximum Required For Hover	3,269.03
Maximum Available	6,067.62

TABLE B.1 (Continued)
ARMY_CORPS_REAR_AREA_SURVEILLANCE_MISSION
Single_rotor
Four_stroke

CLIMB POWER
Fri Jul 28 12:41:10 1989

stage =	1.00	Hours =	0.25
Altitude =	5,000.00	Payload =	18,550.00
Fineness ratio =	2.00	Ballonet design alt. =	10,000.00
Wing span/Env. dia. =	0.50	Blade span/Env. dia. =	0.50
ARwing =	4.00	ARblade =	4.00
Wing Area =	1,282.33	Blade Area =	1,282.33
Wing Span =	71.62	Blade Span =	71.62

AEROSTAT DIAMETER (DIAenv): 143
AEROSTAT VOLUME (VOLenv): 3077561

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	WING	BLADE	TAIL	ENVELOPE
CL	0.235	0.260	0.079	0.001
LIFT	37.382	41.328	19.849	1.441
CDI	0.005	0.005	0.000	0.000
DI	153.075	169.233	13.621	4.911
ALPHA	2.144	2.370	0.788	0.788

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CLIMB SPEED	
True Airspeed (ft/sec)	101.34
Vertical Velocity (ft/sec)	5.55

CLIMB SHP REQUIREMENTS	
SHP (Climb Power)	331.27
SHP (Induced Lift)	104.67
SHP (Aerostat Profile)	1,951.72
SHP (Wing Profile)	192.34
SHP (Blade Profile)	384.68
SHP (Long. Cable Profile)	124.67
SHP (Rot. Cable Profile)	107.45
SHP (Nacelle Profile)	36.00
SHP (Cabin Profile)	39.37
SHP (Tail Profile)	414.34
SHP (Payload Profile)	313.33
SHP (Sling Cable Profile)	67.62

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TOTAL CLIMB SHP REQUIRED	4,067.44

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Fuel Wt. Burned For Stage	498.84
Fuel Wt. Total at beginning of stage	42,406.97
Ballast Wt. at end of stage	0.00
Ballast Wt. at beginning of stage	0.00
Total Wt. at beginning of stage	163,808.87
Buoyancy @ Altitude	143,611.65
Initial Aerodynamic Lift	20,195.73
Final Aerodynamic Lift	19,696.89

TABLE B.1 (Continued)
ARMY_CORPS_REAR_AREA_SURVEILLANCE_MISSION
Single_rotor
Four_stroke

CRUISE POWER
Fri Jul 28 12:41:12 1989

stage =	2.00	Hours =	4.00
Altitude =	5,000.00	Payload =	18,550.00
Fineness ratio =	2.00	Ballonet design alt. =	10,000.00
Wing span/Env. dia. =	0.50	Blade span/Env. dia. =	0.50
ARwing =	4.00	ARblade =	4.00
Wing Area =	1,282.33	Blade Area =	1,282.33
Wing Span =	71.62	Blade Span =	71.62

AEROSTAT DIAMETER (DIAenv): 143
EROSTAT VOLUME (VOLenv): 3077561

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	WING	BLADE	TAIL	ENVELOPE
CL	0.213	0.236	0.072	0.001
LIFT	37.382	41.328	19.849	1.441
CDI	0.004	0.004	0.000	0.000
DI	126.040	139.344	11.215	4.043
LPHA	1.946	2.151	0.715	0.715

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CRUISE SPEED
True Airspeed (ft/sec) 101.34

CRUISE SHP REQUIREMENTS

SHP (Induced lift)	86.18
SHP (Aerostat Profile)	1,951.72
SHP (Wing Profile)	192.34
SHP (Blade Profile)	384.68
SHP (Long. Cable Profile)	124.67
SHP (Rot. Cable Profile)	107.45
SHP (Nacelle Profile)	36.00
SHP (Cabin Profile)	39.37
SHP (Tail Profile)	414.34
SHP (Payload Profile)	313.33
SHP (Sling Cable Profile)	67.62
SHP (Sled Drag Profile)	0.00

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TOTAL CRUISE SHP REQUIRED 3,717.69

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Fuel Wt. Burned For Stage 7,249.85

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uel Wt. Total at beginning of stage 41,908.13

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Ballast Wt. at end of stage 0.00
allast Wt. at beginning of stage 0.00

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Total Wt. at beginning of stage 163,310.02

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uoyancy @ Altitude 143,611.65

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Initial Aerodynamic Lift 19,696.89
inal Aerodynamic Lift 12,447.04

TABLE B.1 (Continued)
ARMY_CORPS_REAR_AREA_SURVEILLANCE_MISSION
Single_rotor
Four_stroke

CLIMB POWER
Fri Jul 28 12:41:13 1989

stage =	3.00	Hours =	0.25
Altitude =	10,000.00	Payload =	18,550.00
Fineness ratio =	2.00	Ballonet design alt. =	10,000.00
Wing span/Env. dia. =	0.50	Blade span/Env. dia. =	0.50
ARwing =	4.00	ARblade =	4.00
Wing Area =	1,282.33	Blade Area =	1,282.33
Wing Span =	71.62	Blade Span =	71.62

AEROSTAT DIAMETER (DIAenv): 143
AEROSTAT VOLUME (VOLenv): 3077561

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	WING	BLADE	TAIL	ENVELOPE
CL	0.144	0.159	0.048	0.001
: LIFT	37.382	41.328	19.849	1.441
CDI	0.002	0.002	0.000	0.000
DI	57.254	63.298	5.095	1.837
ALPHA	1.311	1.450	0.482	0.482

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CLIMB SPEED

True Airspeed (ft/sec)	101.34
Vertical Velocity (ft/sec)	5.55

CLIMB SHP REQUIREMENTS

SHP (Climb Power)	202.60
SHP (Induced Lift)	39.15
SHP (Aerostat Profile)	1,951.72
SHP (Wing Profile)	192.34
SHP (Blade Profile)	384.68
SHP (Long. Cable Profile)	145.47
SHP (Rot. Cable Profile)	107.45
SHP (Nacelle Profile)	36.00
SHP (Cabin Profile)	39.37
SHP (Tail Profile)	483.46
SHP (Payload Profile)	365.60
SHP (Sling Cable Profile)	78.90

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OTAL CLIMB SHP REQUIRED 4,026.72

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Fuel Wt. Burned For Stage 400.84

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uel Wt. Total at beginning of stage 34,658.28

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allast Wt. at end of stage 0.00
allast Wt. at beginning of stage 0.00

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Total Wt. at beginning of stage 156,060.18

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Buoyancy @ Altitude 143,611.65

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nitial Aerodynamic Lift 12,447.04
inal Aerodynamic Lift 12,046.19

TABLE B.1 (Continued)
ARMY_CORPS_REAR_AREA_SURVEILLANCE_MISSION
Single_rotor
Four_stroke

CRUISE POWER
Fri Jul 28 12:41:14 1989

stage =	4.00	Hours =	16.00
Altitude =	10,000.00	Payload =	18,550.00
Fineness ratio =	2.00	Ballonet design alt. =	10,000.00
Wing span/Env. dia. =	0.50	Blade span/Env. dia. =	0.50
ARwing =	4.00	ARblade =	4.00
Wing Area =	1,282.33	Blade Area =	1,282.33
Wing Span =	71.62	Blade Span =	71.62

AEROSTAT DIAMETER (DIAenv): 143
EROSTAT VOLUME (VOLenv): 3077561

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	WING	BLADE	TAIL	ENVELOPE
CL	0.108	0.119	0.036	0.001
LIFT	37.382	41.328	19.849	1.441
CDI	0.001	0.001	0.000	0.000
DI	32.062	35.446	2.853	1.029
LPHA	0.981	1.085	0.361	0.361

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CRUISE SPEED

True Airspeed (ft/sec)	101.34

CRUISE SHP REQUIREMENTS

SHP (Induced lift)	21.92
SHP (Aerostat Profile)	1,951.72
SHP (Wing Profile)	192.34
SHP (Blade Profile)	384.68
SHP (Long. Cable Profile)	145.47
SHP (Rot. Cable Profile)	107.45
SHP (Nacelle Profile)	36.00
SHP (Cabin Profile)	39.37
SHP (Tail Profile)	483.46
SHP (Payload Profile)	365.60
SHP (Sling Cable Profile)	78.90
SHP (Sled Drag Profile)	0.00

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TOTAL CRUISE SHP REQUIRED 3,806.90

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Fuel Wt. Burned For Stage 24,140.97

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Fuel Wt. Total at beginning of stage 34,257.44

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Ballast Wt. at end of stage 12,094.78
Ballast Wt. at beginning of stage 0.00

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Total Wt. at beginning of stage 155,659.33

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Buoyancy @ Altitude 143,611.65

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Initial Aerodynamic Lift 12,046.19
Final Aerodynamic Lift 0.00

TABLE B.1 (Continued)
ARMY_CORPS_REAR_AREA_SURVEILLANCE_MISSION
Single_rotor
Four_stroke

DESCENT POWER
Fri Jul 28 12:41:15 1989

stage =	5.00	Hours =	0.25
Altitude =	5,000.00	Payload =	18,550.00
Fineness ratio =	2.00	Ballonet design alt. =	10,000.00
Wing span/Env. dia. =	0.50	Blade span/Env. dia. =	0.50
ARwing =	4.00	ARblade =	4.00
Wing Area =	1,282.33	Blade Area =	1,282.33
Wing Span =	71.62	Blade Span =	71.62

AEROSTAT DIAMETER (DIAenv): 143
AEROSTAT VOLUME (VOLenv): 3077561

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	WING	BLADE	TAIL	ENVELOPE
CL	0.000	0.000	0.000	0.000
C LIFT	0.000	0.000	0.000	0.000
CDI	0.000	0.000	0.000	0.000
DI	0.000	0.000	0.000	0.000
ALPHA	0.000	0.000	0.000	0.000

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DESCENT SPEED	
True Airspeed (ft/sec)	101.34
Vertical Velocity (ft/sec)	-5.55
DESCENT SHP REQUIREMENTS	
SHP (Descent Power)	-0.00
SHP (Induced Lift)	0.00
SHP (Aerostat Profile)	1,951.72
SHP (Wing Profile)	192.34
SHP (Blade Profile)	384.68
SHP (Long. Cable Profile)	124.67
SHP (Rot. Cable Profile)	107.45
SHP (Nacelle Profile)	36.00
SHP (Cabin Profile)	39.37
SHP (Tail Profile)	414.34
SHP (Payload Profile)	313.33
SHP (Sling Cable Profile)	67.62

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TOTAL DESCENT SHP REQUIRED 3,631.51

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Fuel Wt. Burned For Stage 445.38

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Fuel Wt. Total at beginning of stage 10,116.46

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Ballast Wt. at end of stage 12,540.16
Ballast Wt. at beginning of stage 12,094.78

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Total Wt. at beginning of stage 143,613.14

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Buoyancy @ Altitude 143,611.65

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Initial Aerodynamic Lift 0.00

: B.1 (Continued)
ARMY_CORPS_REAR_AREA_SURVEILLANCE_MISSION
Single_rotor
Four_stroke

CRUISE POWER
Fri Jul 28 12:41:16 1989

stage =	6.00	Hours =	4.00
Altitude =	5,000.00	Payload =	18,550.00
Fineness ratio =	2.00	Ballonet design alt. =	10,000.00
Wing span/Env. dia. =	0.50	Blade span/Env. dia. =	0.50
ARwing =	4.00	ARblade =	4.00
Wing Area =	1,282.33	Blade Area =	1,282.33
Wing Span =	71.62	Blade Span =	71.62

AEROSTAT DIAMETER (DIAenv): 143
AEROSTAT VOLUME (VOLenv): 3077561

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	WING	BLADE	TAIL	ENVELOPE
CL	0.000	0.000	0.000	0.000
% LIFT	0.000	0.000	0.000	0.000
CDI	0.000	0.000	0.000	0.000
DI	0.000	0.000	0.000	0.000
ALPHA	0.000	0.000	0.000	0.000

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CRUISE SPEED

True Airspeed (ft/sec)	101.34

CRUISE SHP REQUIREMENTS

SHP (Induced lift)	0.00
SHP (Aerostat Profile)	1,951.72
SHP (Wing Profile)	192.34
SHP (Blade Profile)	384.68
SHP (Long. Cable Profile)	124.67
SHP (Rot. Cable Profile)	107.45
SHP (Nacelle Profile)	36.00
SHP (Cabin Profile)	39.37
SHP (Tail Profile)	414.34
SHP (Payload Profile)	313.33
SHP (Sling Cable Profile)	67.62
SHP (Sled Drag Profile)	0.00

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TOTAL CRUISE SHP REQUIRED 3,631.51

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Fuel Wt. Burned For Stage 7,126.07

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uel Wt. Total at beginning of stage 9,671.08

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allast Wt. at end of stage 19,666.23
allast Wt. at beginning of stage 12,540.16

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Total Wt. at beginning of stage 143,613.14

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Buoyancy @ Altitude 143,611.65

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nitial Aerodynamic Lift 0.00
inal Aerodynamic Lift 0.00

TABLE B.1 (Continued)
ARMY_CORPS_REAR_AREA_SURVEILLANCE_MISSION
Single_rotor
Four_stroke

DESCENT POWER
Fri Jul 28 12:41:18 1989

stage =	7.00	Hours =	0.25
Altitude =	0.00	Payload =	18,550.00
Fineness ratio =	2.00	Ballonet design alt. =	10,000.00
Wing span/Env. dia. =	0.50	Blade span/Env. dia. =	0.50
ARwing =	4.00	ARblade =	4.00
Wing Area =	1,282.33	Blade Area =	1,282.33
Wing Span =	71.62	Blade Span =	71.62

AEROSTAT DIAMETER (DIAenv): 143
AEROSTAT VOLUME (VOLenv): 3077561

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	WING	BLADE	TAIL	ENVELOPE
CL	0.000	0.000	0.000	0.000
% LIFT	0.000	0.000	0.000	0.000
CDI	0.000	0.000	0.000	0.000
DI	0.000	0.000	0.000	0.000
ALPHA	0.000	0.000	0.000	0.000

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DESCENT SPEED	
True Airspeed (ft/sec)	101.34
Vertical Velocity (ft/sec)	-5.55
DESCENT SHP REQUIREMENTS	
SHP (Descent Power)	-0.00
SHP (Induced Lift)	0.00
SHP (Aerostat Profile)	1,951.72
SHP (Wing Profile)	192.34
SHP (Blade Profile)	384.68
SHP (Long. Cable Profile)	107.42
SHP (Rot. Cable Profile)	107.45
SHP (Nacelle Profile)	36.00
SHP (Cabin Profile)	39.37
SHP (Tail Profile)	357.02
SHP (Payload Profile)	269.99
SHP (Sling Cable Profile)	58.26

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TOTAL DESCENT SHP REQUIRED 3,504.25

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Fuel Wt. Burned For Stage 525.64

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Fuel Wt. Total at beginning of stage 2,545.02

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Ballast Wt. at end of stage 20,191.86
Ballast Wt. at beginning of stage 19,666.23

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Total Wt. at beginning of stage 143,613.14

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Buoyancy @ Altitude 143,611.65

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Initial Aerodynamic Lift 0.00
Final Aerodynamic Lift 0.00